CRESTMOOR CANYON
GEOLOGIC AND GEOTECHNICAL INVESTIGATION
City of San Bruno, California

for
CITY OF SAN BRUNO
567 El Camino Real
San Bruno, California 94066-4299

by
COTTON, SHIRES AND ASSOCIATES, INC.
330 Village Lane
Los Gatos, California 95030
March 2008

March 14, 2008
G0067

Mr. Chris Coles
Public Works Department
CITY OF SAN BRUNO
567 El Camino Real
San Bruno, California 94066-4299

SUBJECT: **Geologic and Geotechnical Investigation**
RE: Crestmoor Canyon
San Bruno, California

Dear Mr. Coles:

Cotton, Shires and Associates, Inc. (CSA), is pleased to submit the following report in which we describe the findings and conclusions of our Geologic and Geotechnical Investigation of Crestmoor Canyon for the City of San Bruno (City), California. This investigation was performed in accordance with our Agreement for Consultant Services with the City dated April 25, 2007. For clarity, we have provided an Executive Summary at the beginning of the report, followed by the Technical Report.

We appreciate the opportunity to have been of service to you on this project. If you have any questions regarding this report or any aspect of our investigation, please call.

Very truly yours,

COTTON, SHIRES AND ASSOCIATES, INC.

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CRESTMOOR CANYON
GEOLOGIC AND GEOTECHNICAL INVESTIGATION
City of San Bruno, California

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APPENDIX B

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

- Geotechnical investigation of Crestmoor Canyon by Cotton, Shires and Associates, Inc. (CSA) resulted in the identification of nine (9) priority sites where either additional design evaluations and/or timely implementation of remedial measures are warranted. Six of the priority sites present moderate to high risk to existing improvements and/or private property.

- Seven of the nine priority sites have constraints attributed to discharge of concentrated storm water onto native or artificial fill slopes. Due to the steep canyon topography, combined with relatively weak and erodible earth materials, local slopes are sensitive to concentrated stormwater discharge.

- Priority sites have been identified as a first step in reducing property damage due to potential future slope failures. The City may wish to rank the priority sites for order of remediation considering identified potential risk levels, parties responsible for repair, available funding sources and community benefits.

- Relatively high risks have been identified to existing City facilities at Priority Site 1 - San Bruno Avenue Fill Slope Erosion and Instability, and Priority Site 2 - Undermining of Outfall Structure at Glenview Park. Risks at these two sites are related to extensive erosional incision, and active landsliding north of San Bruno Avenue.

- Seasons of unusually heavy rainfall appear to have triggered significant slope instability and extensive erosion in the past where runoff has been concentrated onto canyon slopes. Where City storm runoff facilities discharge collected water onto canyon slopes, the outfalls should be periodically monitored during and after intense winter storm periods. Areas exhibiting erosion and/or distress should receive appropriate remedial design measures.

- Many of the concrete V-ditch systems located within or adjacent to residential backyards are currently non-functional and present moderate to high risks of adversely impacting slope stability. Near-term efforts are needed to ensure that these potential problem areas receive timely remediation. Specific V-ditch system priority areas are identified in the following report.

- In most cases, identified drainage problems require implementation of necessary facility improvements or maintenance to ensure that concentrated water is properly conveyed to suitable discharge locations. The details of appropriate remedial design measures are specific to each site, and should be based on supplemental evaluations.

- Several existing Old, Dormant, and Active Landslides were identified during canyon mapping, including deep rotational failure, earthflow, and debris flow type

landslides. Surface drainage should be carefully controlled where these landslides are located in close proximity to private property or existing City improvements. Specific landslide area sites warranting remedial drainage improvements are discussed in the following report.

- Supplemental geotechnical investigation of landslide areas could identify other appropriate remedial measures such as subsurface dewatering systems or construction of stitch piers to isolate instability from nearby improvements.

- Many of the identified landslides have occurred in areas altered by grading activities or impacted by post-development drainage systems. In general, existing landslides should be considered to have the potential for upslope, retrogressive enlargement, especially when concentrated drainage is directed toward masses of ground previously displaced by landsliding.

- Three earthquake faults have been mapped adjacent to, or extending through, the Canyon limits. The potentially active Serra fault is located at the far eastern end of the canyon study area, and recent studies have asserted that this fault should be classified as active, but the State has not collected sufficient information to rezone this fault. Two other unnamed fault traces have been mapped along the western portion of the canyon. These mapped fault traces are likely associated with past movement along the San Andreas fault zone, with the master trace located immediately east and approximately parallel to Skyline Boulevard.

TECHNICAL REPORT

CRESTMOOR CANYON
GEOLOGIC AND GEOTECHNICAL INVESTIGATION
City of San Bruno, California

1.0 PURPOSE AND SCOPE OF WORK

The purpose of this investigation was to identify and evaluate site landslide and slope stability conditions, identify potential drainage control issues, provide an assessment of risk to affected properties, prepare alternative mitigation concepts, and to prepare a map of Crestmoor Canyon illustrating site engineering geologic conditions. In order to satisfy these objectives, Cotton, Shires and Associates, Inc. (CSA) performed the following scope of work:

1. Background Research - Available geotechnical investigation reports pertinent to canyon slope stability and erosional problems were reviewed. Previous findings were incorporated into our final maps and assessments of risk.

2. Evaluation of Aerial Photographs - Stereoscopic pairs of aerial photographs were examined to identify local geomorphic conditions and to assess their relationships with landsliding in the area. Data regarding past grading activities were utilized to determine the limits of artificial fill prisms and graded slopes. A total of nine (9) sets of stereo photographs from the years 1946 to 2005 were obtained and evaluated.

3. Review of Published Data - Pertinent maps depicting local topographic and geologic conditions were reviewed and considered when plotting geologic bedrock units and fault traces across the canyon.

4. Site Reconnaissance and Engineering Geologic Mapping - Approximately eight (8) person days of site reconnaissance were completed, and we prepared a detailed engineering geologic map of the subject property on the provided topographic base map. We prepared selective engineering geologic cross sections based on engineering geologic mapping. No subsurface exploration was conducted as part of this preliminary investigation. Approximately 300 digital photographs of canyon conditions were taken and 133 of the most representative images are presented on a CD included with this report.

5. Technical Analyses - Field and office data were analyzed to characterize existing site conditions and allow evaluation of risks

presented by apparent slope stability conditions. We formulated a list of nine (9) priority sites identified around the canyon and have prepared short summary assessments of each site.

6. Drainage Evaluations - Observed site drainage control structures are illustrated on the enclosed Crestmoor Canyon Engineering Geologic Map. Descriptions of the existing conditions of drainage control structures are included in the text of the report. Data regarding historic rainfall is presented in Appendix A.

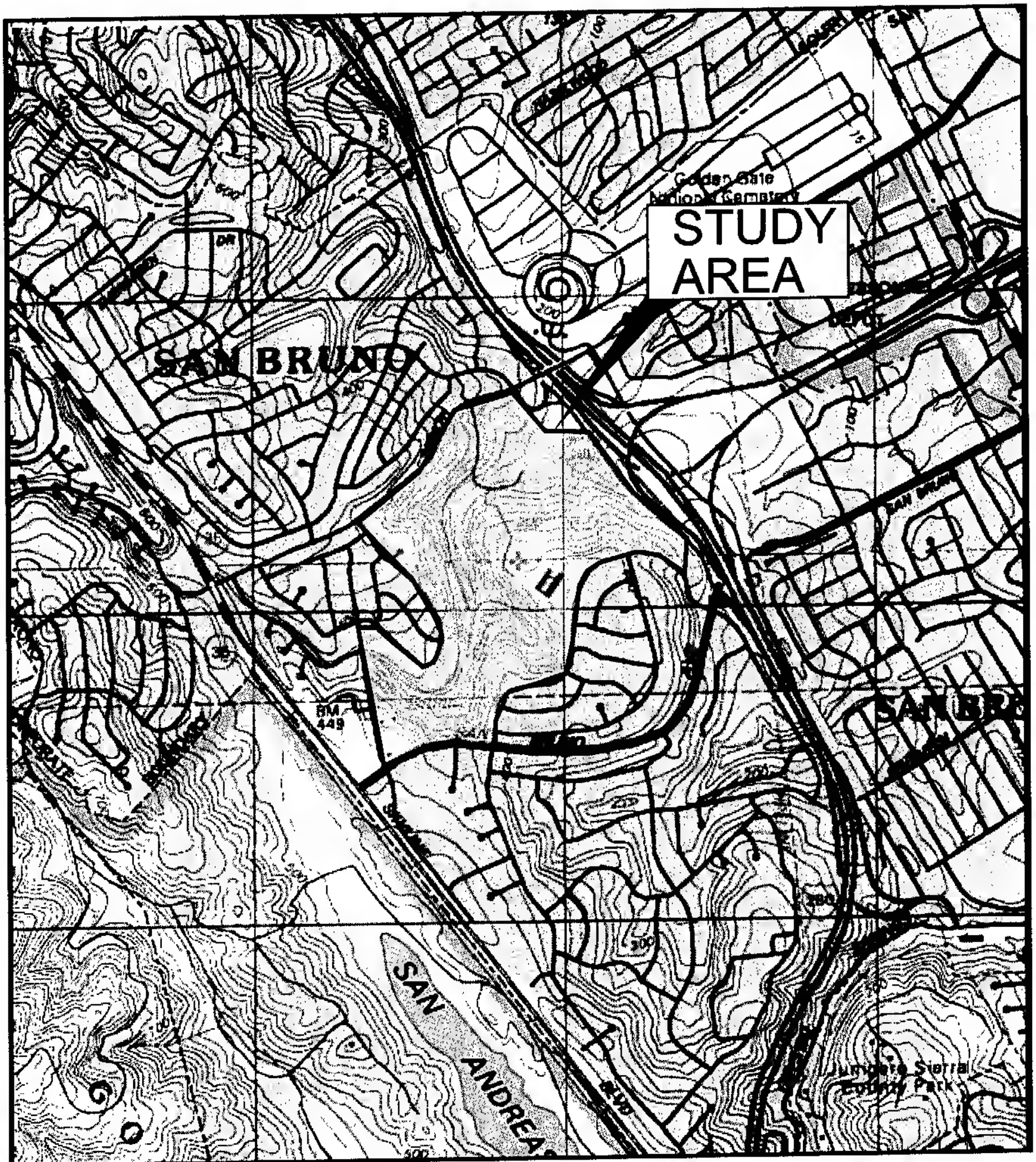
7. Presentation of Findings - We prepared this report and accompanying illustrations to summarize the findings of our investigation. Engineering geologic site conditions are depicted on the Engineering Geologic Map (Plate 1, in pocket), priority site locations are shown on Plate 2 (in pocket), and our ground surface photographs are indexed on Plate 3 (in pocket). Digital scans of historic aerial photographs and selected ground photographs are included on enclosed CDs (Appendix A, in pocket).

2.0 SITE CHARACTERISTICS

2.1 Regional Geologic Setting

The boundaries of the Crestmoor Canyon study area are depicted on the Site Location Map (Figure 1). The subject property is located in the seismically active San Francisco Bay region between the San Andreas fault zone and the mapped trace of the Serra fault (Bonilla, 1965; Brabb and Pampeyan, 1983). The most active of these faults is the San Andreas with the apparent master trace mapped approximately 500 feet to the southwest of the point where San Bruno Creek enters Crestmoor Canyon beneath Glenview Drive. Relatively rapid tectonic uplift has occurred due to crustal movement along these fault systems, and has resulted in steep slopes and deeply incised drainages such as those in the study area.

The central portion of Crestmoor Canyon is underlain, at depth, by sandstone, siltstone, conglomerate, and claystone bedrock of the Tertiary age Merced Formation. This formation has been described as moderately consolidated, but friable, grayish-orange when weathered, thick-bedded to massive. The bedrock is locally overlain by colluvial soils (including landslide debris) and artificial fill. The northeastern and southwestern margin areas of the canyon are underlain by bedrock of the Franciscan Complex (primarily graywacke, greenstone, and sheared rock) of Cretaceous and Jurassic Periods.



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COTTON, SHIRES & ASSOCIATES, INC.
CONSULTING ENGINEERS AND GEOLOGISTS

SITE LOCATION MAP
CRESTMOOR CANYON
SAN BRUNO, CALIFORNIA

GEO/ENG. BY	SCALE	PROJECT NO.
MM	1"=4000'	G0067
APPROVED BY	DATE	FIGURE NO.
JW	3/14/08	1

2.2 General Site Conditions

Crestmoor Canyon was incised by flow of San Bruno Creek and is characterized primarily by steep north-, west-, and east-facing slopes. Upper portions of these slopes have been altered by grading activities that largely took place in the mid to late 1950's. These grading activities were undertaken to create relatively level building pads for adjacent residential structures that are located along the western and southeastern perimeter of the canyon. Grading involved removal of material from ridgetop areas and placement of this material as fill in broad drainages, or swales. Ungraded portions of hillsides within the canyon average approximately 28 degrees inclination (1.85:1, H:V) and fill slopes average 31 degrees (1.7:1). Many of the fill slopes are, therefore, steeper than the current generally accepted standard in the Bay area of 26 degrees inclination (2:1). Much of the flanking canyon slopes are covered by oak, eucalyptus, and pine trees. Dense brush covered slopes are found where tree cover has been disturbed.

Several different types of earth materials were identified on the subject property. These include: sandstone, siltstone, and conglomerate bedrock of the Merced Formation; greywacke and greenstone of the Franciscan Complex; colluvium; artificial fill; and landslide debris. The distribution of identified earth materials in the colluvium is illustrated on the enclosed Engineering Geologic Map (Plate 1).

Colluvium was identified overlying bedrock across most of the site. Colluvium is derived from the downslope movement of weathered bedrock and soil materials. The colluvium at the site may be characterized as clayey sand to silty clay of dark to moderate yellowish brown and dark yellowish orange color, moderate density and friable hardness.

The artificial fill identified in the canyon is predominantly of two types which reflect the Franciscan and Merced Formation source materials. The fill boundaries shown on the Engineering Geologic Map were determined based on direct observation of fill materials, changes in slope inclination, and the locations of adjacent ridges and swales on the hillside and are, therefore, approximate. Areas of grading disturbance observed on aerial photographs were also considered when plotting fill boundaries.

2.3 Landslides on the Subject Property

Several of the observed landslides within the canyon displayed geomorphic features indicating probable shallow rotational ground failures of artificial fill and colluvium which then rapidly mobilized into debris flows. Due to the steep slopes at the site, abundant subsurface water and the grain-size distribution and strength of the colluvial materials, several of the historic landslides (identified in aerial photographs) mobilized as debris flows. Debris flows are rapid moving masses of saturated earth materials that move by internal shearing, very similar to the flow of wet concrete.

Debris flows can form when water pressure in the pore spaces of the landslide mass increases beyond critical limits.

Rotational landslides were also observed that involve movement of a mass of material along a discrete, somewhat circular shear surface. Rotational failures generally display arcuate headscarps and leave spoon-shaped cavities. Landslides can be generated due to changes in slope conditions. These changes may include an increase in slope angle through grading, surcharge loading of natural slope materials by fill placement, and increases in erosion or soil water contents by modifications to drainage.

Man-made changes in slope conditions often trigger landslides. Most of the slope failures in the investigation area appear to have occurred in areas altered by grading activities or areas impacted by post-development drainage systems. Several of the landslides appear to involve slopes that were steepened and loaded by addition of artificial fill that may not have been properly keyed (by today's standards) into bedrock. Other landslides appear to involve slopes that were steepened by excavation near the toes or slopes, or by undermining caused by erosion.

3.0 GEOTECHNICAL CONSTRAINTS

3.1 Site Landslides - Historical Observations

Nine sets of historic, stereo-paired aerial photographs of the subject site were obtained covering the time period from 1946 through 2005. From examination of these photographs, we have prepared the following chronological summary of site slope instability. The first group of historic landslides was observed in photographs taken in July 1946. Several shallow, relatively small debris flow failures were observed in the central portion of the canyon. These failures were located at relatively low positions on flanking canyon slopes. Debris from these failures was apparently deposited into San Bruno Creek. Aerial photographs reveal evacuated cavities that are barren of vegetation. These failures may have been associated with high peak rainfall events of early 1946. Two of the largest failures are depicted as Old Landslides (Ols) on Plate 1.

Additional, new young landslides were observed in aerial photographs of May 1955 in the southwestern corner of the canyon below the church off of Glenview Drive on northeast-facing slopes. These landslides appear to be rotational failures on the order of 200 to 300 feet in length. Relatively heavy precipitation in early 1952 may have triggered these failures. While current topographic data in the vicinity of these past failures appears anomalous, and suspicious in terms of landsliding, we did not confirm the presence of these past failures during field mapping because or poor access and very dense vegetation.

The 1955 photos also clearly revealed large scale landsliding immediately northeast of Crestmoor Elementary School as depicted on Plate 1. These landslides appear to be a combination of deep-seated rotation failures and shallower earth flow/debris flow failures. Slope instability appears to be enlarging (retrogressing upslope) relatively slowly in this area but may eventually impact existing school yard facilities. No existing school buildings or residences currently appear to be in imminent risk for this complex of multiple landslides.

Significant new landslides were not observed in photographs from 1958 and 1977. However, June 1983 photographs reveal three recently active landslides immediately south of the eastern terminus of Concord Way. We understand these failures occurred on fill slopes and a subsequent large-scale grading repair was undertaken to stabilize this general area. Signs of recently active shallow landsliding and erosion were also observed in 1983 photographs below residences located at 1620, 1630, and 1636 Claremont Drive. Tied-back soldier pile retaining walls were later installed to address failing slopes in this vicinity. Our recent inspections have confirmed ongoing shallow landsliding (below installed retaining walls) in this slope area south of Claremont Drive (see Priority Site 3 Assessment).

Another area of apparent large scale, deep landsliding and significant erosion was observed in 1983 photographs near a culvert outfall north of San Bruno Avenue. Slope failures in this area have been ongoing at least since 1983 and a deep gully now extends into artificial fill materials that support the public roadway. The undermined condition of existing fill materials in this area is likely to lead to upslope migration of instability toward San Bruno Avenue at some point in the future (see Priority Site 1 Assessment).

Over the last few winters, new landsliding has occurred east of residences located from 1420 to 1460 Claremont Drive. A grading repair and subdrain system was completed in the fall of 2007 to stabilize this vicinity of active landsliding. Slope failure in this vicinity likely has resulted from poor control of collected, concentrated surface drainage, placement of fill materials over native soils without sufficient keying and benching, and construction of fill slopes at inclinations significantly steeper than 2:1 (horizontal:vertical).

Immediately north of the above-noted grading repair, additional dormant landslides have been identified (east of residences located at 1360 through 1420 Claremont Drive). The observed landsliding may have initially occurred prior to the 1950's mass grading operations for construction of residential building pads. Observed signs of past ground displacement suggest that these dormant landslides underwent deep rotational failures. Proper control of concentrated surface drainage is required to avoid reactivation and upslope retrogression of these currently dormant landslides (see Priority Site 5 Assessment).

3.2 Additional Geotechnical and Drainage Constraints

Additional areas were identified along the perimeter of the canyon where existing City and private improvements appear to be at risk from degraded conditions of existing storm drainage facilities.

At Glenview Park, the concrete-lined splash apron below the culvert discharge has become undercut by erosion. A May 1993 Geotechnical Evaluation (letter) by Rogers/Pacific indicates that the existing apron structure was built in approximately 1959. By the early 1980's, undercutting of the apron had apparently initiated and a large plunge pool had formed at the base of the concrete flow chute. Significant portions of the lower apron have now broken off and drainage discharge at this location should be anticipated to progressively undermine the splash apron and erode portions of the fill prism supporting Glenview Drive (see Priority Site 2 Assessment).

Additional significant erosional damage was observed in the vicinity of an existing culvert outfall below 2450 Crestmoor Drive. In this area, gullies from 6 to 9 feet in depth have formed near the toe area of an existing fill prism that support portions of existing residential lots adjacent to Crestmoor Drive. Subdued signs of dormant landsliding were observed within the fill prism near the apparent culvert outfall (see Priority Site 4 Assessment).

Existing concrete V-ditches, installed during initial building pad grading and residential construction, are in very poor condition (essentially non-functional). Significantly damaged V-ditches are located near backyard residential fence lines of properties along the eastern portion of Crestmoor Drive, and at multiple locations of properties adjoining the canyon along Claremont Drive. The current poor condition of these V-ditches results in partial collection of concentrated storm runoff from impermeable residential hardscape areas and roofs. Collected drainage is discharged at points where V-ditch continuity has been lost. Where concentrated water is discharged onto steep canyon slopes, both signs of erosion or slope instability were commonly observed (See Priority Site 7 and Priority Site 8 Assessments).

3.3 Priority Site Assessments

Our preliminary investigation of the canyon resulted in identification of nine (9) priority sites where additional investigation, evaluation and timely implementation of remedial measures are warranted. Appendix A includes copies of our focused summaries of each priority site. The locations of the nine Priority Sites are illustrated on Plate 2 (in pocket). We conclude that the highest priority areas are Sites 1, 2, 3, 4, 5, and 8. Other important, but not as high risk areas (at this time) include Sites 6, 7, and 9. In the following Table, we summarize priority site hazards, relative risks, recommended action, and relative approximate remedial cost ranges. In addition, we have indicated whether the priority site involves apparent or potential interactions between City and private properties.

Priority Site	Hazards	Relative Risk	Recommended Action	Relative Remedial Cost Range	Property Interactions with Private
1	Erosion Landsliding	Moderate to High	Supplemental Investigation, Remedial Measures	$200k to $1 mil	No
2	Erosion	Moderate to High	Supplemental Evaluation, Remedial Measures	$250k to $1.5 mil	No
3	Shallow Landsliding	Moderate	Supplemental Investigation, Remedial Measures	$150k to $400k	Yes
4	Erosion Landsliding	Low to Moderate	Supplemental Investigation, Limited Remediation	$50k to $300k	Yes
5	Deep Landsliding	Moderate to High	Supplemental Evaluation, Remediation	$50k to $1.5 mil	Yes
6	Roadway Fill Settlement / Deformation	Low	Monitoring	-	No
7	Erosion Shallow Instability	Low to Moderate	Supplemental Evaluation, Remedial Measures	$100k to $300k	Yes
8	Erosion Landsliding	Moderate to High	Supplemental Evaluation, Remedial Measures	$75k to $400k	Yes
9	Potential Erosion	Low	Maintenance of Facility	$5k	Yes

4.0 SUMMARY

Over the years, Crestmoor Canyon has been utilized as a drainage discharge area. Due to the steep topography and relatively weak and erodible earth materials that underlie the majority of the canyon, local slopes are sensitive to concentrated storm water discharge. Seven of the nine identified priority sites within the canyon have resulted from artificially concentrated water discharge onto graded and native slopes. In most cases, the fundamental solution to these problem areas is to construct appropriately engineered drainage improvements to properly convey storm runoff to more suitable discharge locations. In a few cases, there may be the option of considering installation of robust slope or channel armoring at the existing point of drainage discharge, and/or along the open channel that conveys discharge across areas of steep slopes. Methods to reduce the energy of flowing water after discharge may also warrant consideration. In areas where slopes have already begun to fail (or deeply erode due to drainage discharge), the slope stabilization methods should be considered in combination with completion of drainage improvements.

In terms of protecting existing City facilities, Priority Site 1 – San Bruno Avenue Fill Slope Erosion and Instability, and Priority Site 2 – Undermining of Outfall Structure at Glenview Park appear to warrant supplemental near-term focused evaluations and implementation of appropriate remedial design.

To reduce the potential for future drainage related impacts to private properties, including the potential for landsliding that may cross property lines between private lots and public canyon land, engineering solutions need to be identified to address currently non-functional storm drainage systems (primarily concrete-lined V-ditch collection systems and associated outfall structures constructed 40 to 50 years ago). The factors that have disrupted existing concrete V-ditch systems include the following:

- Inadequate maintenance (unintentional infilling of ditches with slopes debris/sediment);
- Growth of tree roots beneath ditches displacing concrete structures;
- Creep of soils undermining and shifting ditches;
- Placement of fill materials across ditch alignments;
- Blocking of ditches at fence crossings (in order to contain pets); and
- Direction of additional runoff from new impermeable surfaces into existing ditches such that the maximum design capacity/flow depth is exceeded.

It appears that some combination of maintenance, ditch reconstruction, outfall modification, and other creative engineering solutions will be required to address problems with the existing V-ditches. The conditions of V-ditch systems on residential properties between Claremont Drive and the canyon (particularly identified Priority Sites 5 and 8) appear to warrant supplemental near-term efforts to ensure that these potential problem areas receive timely remediation.

With completion of this preliminary investigation, important progress has been made in the identification of geologic hazards within Crestmoor Canyon. In order to ultimately reduce property damage due to future slope failures within the canyon, we have completed preliminary evaluations of risk levels associated with identified priority sites. Considering identified risk levels, funding sources, and parties responsible for remediation, City deliberations should address ranking of identified impaired canyon areas to receive design and implementation of remedial measures.

5.0 LIMITATIONS

Our services consist of professional opinions and recommendations made in accordance with generally accepted engineering geology and geotechnical engineering principles and practices. No warranty, expressed or implied, or merchantability of fitness, is made or intended in connection with our work, by the proposal for consulting or other services, or by the furnishing of oral or written reports or findings.

6.0 REFERENCES

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Wentworth, et al., 1985, Map of Hillside Materials And Description of Their Engineering Character, San Mateo County, CA, Map I-1257-D, U.S. Geological Survey, scale 1:62,500.

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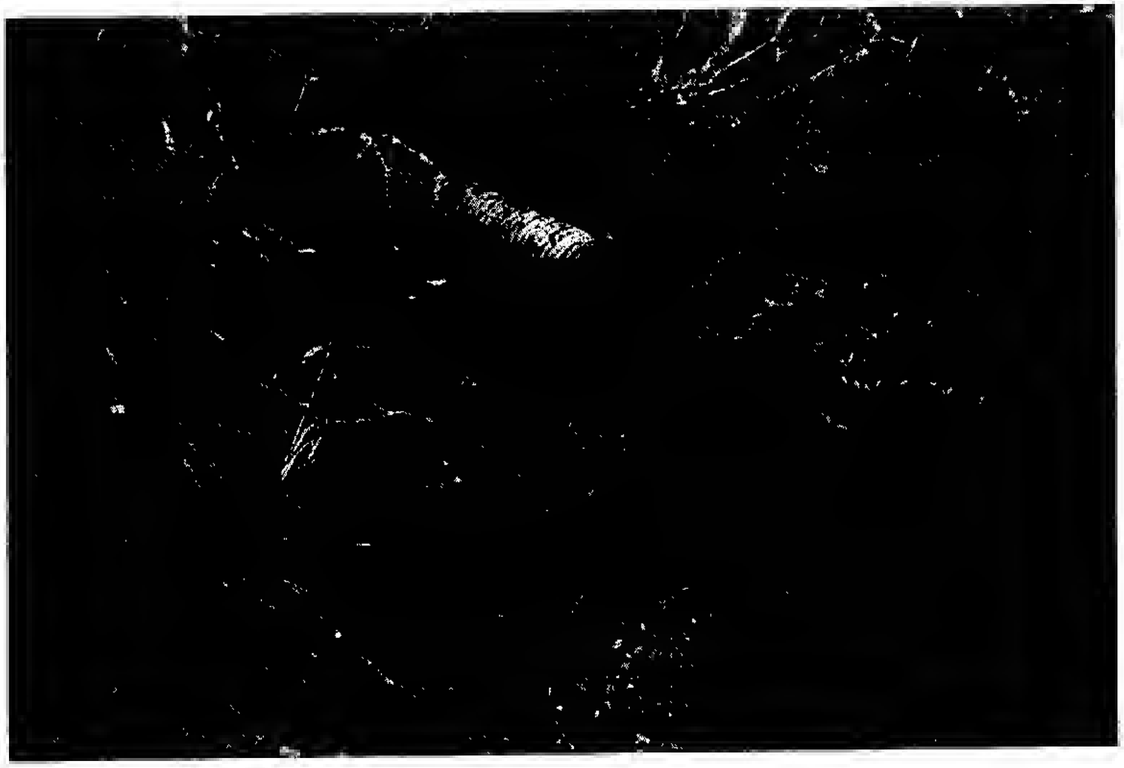
Youd, and Perkins, 1987, Map Showing Liquefaction Susceptibility of San Mateo County, CA, Map I-1257-G, U.S. Geological Survey, scale 1:62,500.

APPENDIX A

Priority Site Assessments

CRESTMOOR CANYON SITE 1

SAN BRUNO AVENUE FILL SLOPE EROSION AND LANDSLIDING



Observed Field Conditions

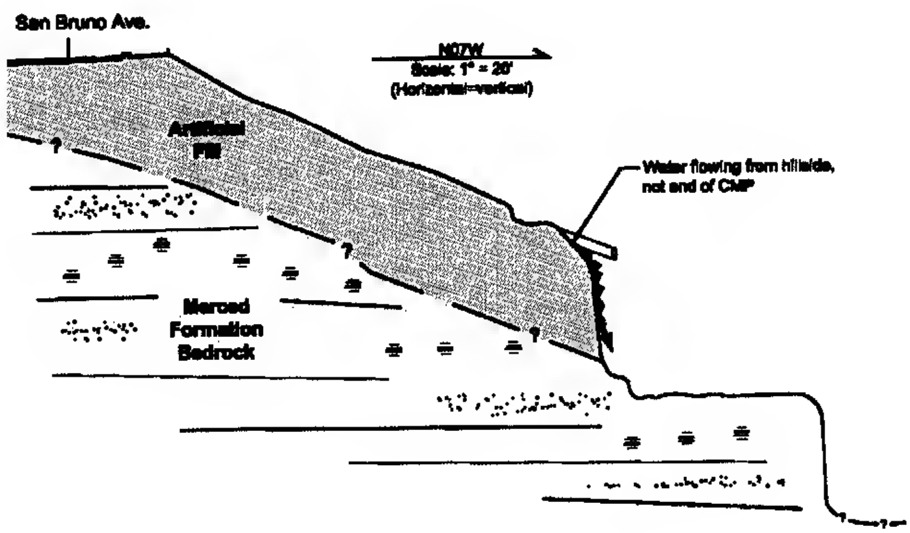
Fill was placed beneath and on the outboard (downslope) side of San Bruno Avenue between Glenview Drive and Crestmoor Drive, possibly for the construction of San Bruno Avenue. A storm drainage culvert (24-inchϕ CMP) runs underneath San Bruno Avenue and discharges onto the north-facing fill slope, approximately 50 feet downslope of the outboard edge of the road. Storm water discharging from the 24-inchϕ CMP has scoured through the existing fill, exposed the underlying bedrock and created a steep gully incision in the slope up to 20 feet deep. The gully has migrated upslope approximately 10 feet from the end of the existing pipe, leaving 10 feet unsupported. We understand that the problem was previously identified and that storm discharge has been diverted to other conduits. However, we noted during several site visits that some water continues to flow from the culvert. Additionally, the bottom of the CMP has corroded throughout its exposed length, resulting in water draining at the slope/pipe interface. Upslope of the existing incised gully the slope exhibits signs of instability; a scarp, approximately 2 feet high, was observed on the slope south of the existing CMP.

Preliminary Risk Assessment

The fill prism supporting San Bruno Avenue has undergone an extensive amount of erosion and continues to erode. Although the majority of the storm run-off has been diverted from this particular culvert a perennial flow of water (variations in volume of flow have not been determined) continues to drain and is contributing to further erosion and slope instability in this area. Fresh scarps are visible upslope of the incised gully. The risk of future enlargement of slope instability and adverse impacts to San Bruno Avenue is **moderate** to **high** under static or seismic conditions.

Recommendations

We recommend that a temporary flexible pipe and connection be attached to the end of the pipe and discharged at a suitable location downslope. The City should monitor this condition including looking for signs of distress in the roadway and downslope instability. If the City chooses to be proactive, then a focused geotechnical investigation could be completed including detailed surveying of the local slopes. An analysis should be completed to address static and seismic factors of safety against failure. Appropriate mitigation alternatives should be outlined as necessary. The corroded sections of the pipe should either be removed, replaced or lined.
(See photos 130-133 on CD showing site conditions)



CRESTMOOR CANYON SITE 2

UNDERMINING OF OUTFALL STRUCTURE, GLENVIEW PARK

Observed Field Conditions

San Bruno Creek flows into the far western portion of Crestmoor Canyon, just below Glenview Park. The creek is fed through two pipes, a 24-inchϕ corrugated steel pipe (CMP) and a 48-inchϕ reinforced concrete pipe (RCP). The two pipes discharge onto a concrete apron that extends approximately 45 feet to the east. At the end of the concrete apron water collects in a pond, approximately 20-feet wide by 40-feet long. A section at the end of the concrete apron has broken off and become detached from the structure resulting in a four-foot high drop.

The concrete apron is equipped with baffles for energy dissipation. The baffles in the center of the concrete apron have worn away resulting in the unimpeded flow of water. At the downstream termination of the concrete apron, scour has undermined the structure, creating a large void underneath the concrete.

Preliminary Risk Assessment

The concrete splash apron is in need of repair to prevent further undermining of the structure. The existing pond could also cause potential failures in the slopes that surround it, or be a source of potential flooding. The hillsides behind the adjacent streets, Claremont Drive and Glenview Drive, are very steep to precipitous. These slopes extend down to the concrete apron and associated pond. The slope behind 970 Glenview Drive experienced a landslide failure in 1993. The risk of additional undermining of the outfall structure is **very high** and the potential for ponding and poorly controlled surface flow to cause instability of adjoining slopes is **moderate** to **high**.

Recommendations

We recommend that the concrete apron be fully repaired and consideration be given to corrective grading to drain the pond area. A topographic survey of the outfall area should be completed and the potential need for buttressing of eroded/undermined slopes should be considered during remedial design.
(See photos 15-19 on CD showing site conditions)

CRESTMOOR CANYON SITE 3

LANDSLIDING AND RETAINING WALL BACKDRAIN FAILURE BELOW 1636 CLAREMONT DRIVE

Observed Field Conditions

This location is the site of several slope repairs dating from 1983 to recent. The most significant landslide repair measures consisted of a soldier pile and lagging wall with tiebacks that borders and supports the rear yards of 1610 through 1636 Claremont Drive.

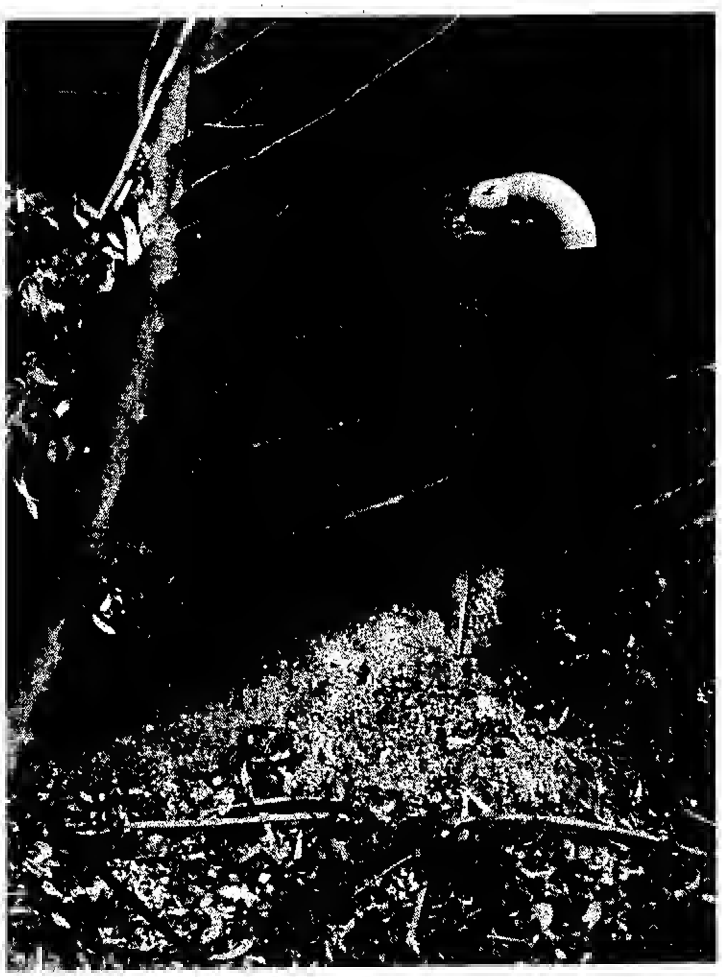
During our field inspection, we noted that recent shallow landsliding has occurred behind 1646, 1636, 1620 and 1600 Claremont Drive. The slope at the base of the retaining wall has moved by landsliding and creep, exposing and in places undermining the base of the wood lagging. Subsequently the drainrock installed behind the retaining wall at 1636 Claremont has begun to ravel out onto the slope below. A drainage pipe located approximately 4 feet above the bottom of the lagging discharges onto the slope.

Preliminary Risk Assessment

The slope behind the noted residences has already undergone repair for damages incurred by landsliding in 1983. With the slope below experiencing continuing instability, the material retained behind the wall (including backdrain gravel) is being undermined and poses the risk of causing distress to the yards immediately upslope. Eventually the retaining wall foundations could be undermined by ongoing landsliding.

Recommendations

The City could continue to maintain the wall by adding lagging where the bottom has been undermined to prevent loss of backfill/backdrain. Alternatively, a focused geotechnical investigation could be conducted to define the limits of slope instability, characterize geotechnical aspects of slope instability and to develop design criteria for appropriate measures to stabilize adjacent slopes.
(See photos 20-25 on CD showing site conditions)



CRESTMOOR CANYON SITE 4

FILL SLOPE FAILURE AT CULVERT OUTLET BELOW 2450 CRESTMOOR DRIVE

Observed Field Conditions

This area is located along the southeastern rim of the canyon, near the intersection of Kingston Drive and Crestmoor Drive. Local slopes have been impacted by adverse discharge of collected storm drainage.

A drop inlet located between 2450 and 2460 Crestmoor Drive conveys collected water to a storm drain culvert that extends down the slope north of the residences and discharges onto the ground surface mid-slope. We were not able to find the exact discharge point at the time of our site visit due to the thick mat of vegetation on the slope.

The slopes within this portion of the canyon are moderately steep and composed of artificial fill. Erosional incision was observed on slopes well below local residences. The local fill slope extends down to an unpaved access road located approximately 200 feet downslope from the top of the canyon rim. A 24 inch ϕ corrugated metal pipe conducts drainage underneath the unpaved road. Walls of the central drainage gully are approximately 6 feet high on the upslope side of the road and approximately 9 feet high immediately downslope. An erosional incision can be seen through the vegetation extending up from the unpaved road toward Crestmoor Drive and appears to terminate somewhere midslope. Heavy vegetation obscures the upper culvert discharge point.

Preliminary Risk Assessment

The risk of continued gully erosion and future slope instability as a direct result of poorly controlled surface drainage is **high**. The risk that slope instability will rapidly expand and impact upslope private properties in the next 2 to 3 years is **low**.

Recommendations

We recommend that additional geotechnical investigation be undertaken of this area. Landsliding and erosional features should be characterized and evaluated to determine appropriate engineering solutions. Mitigation may include corrective grading, placement of check dams or extension of existing culverts and installation of energy dissipaters at pipe outlets.
(See photos 121-123 showing site conditions)

CRESTMOOR CANYON SITE 5

SURFACE DRAINAGE SYSTEM PROBLEMS AND LANDSLIDING LOCATED EAST OF 1360-1420 CLAREMONT DRIVE

Observed Field Conditions

This area is located 5 lots to the north of the intersection of Concord Way extending along the slope behind 7 residences (1360 through 1420 Claremont Drive). Several slope instability features were identified, including an old landslide feature (pre-development), a broken and non-functioning concrete drainage V-ditch, blocked sections of drainage V-ditch, and slope scouring related to drainage diversion. This area is also situated immediately north of three areas of post development landslide repairs, with the most recent repair completed in November 2007.

The area is located on an east-facing hillslope, with topography ranging from steep (up to 26 degree inclination) to very steep (up to 36 degree inclination) extending down to the Canyon access road. The hillside has undergone extensive grading related to residential construction that occurred between 1955 and 1958, resulting in the placement of a large fill prism. A concrete V-ditch was constructed near the top of the fill slope behind the existing residences. The stretch of V-ditch behind 1360 to 1400 Claremont Drive is in poor condition. The V-ditch has been rotated by soil creep processes and no longer has the initial design capacity. A gabion wall has been placed just below the V-ditch behind 1400 Claremont Drive. The wall was presumably placed to help support the V-ditch as mitigation for slope instability. The V-ditch immediately above (north of) the gabion wall is relatively intact.

Scour features were identified on the slope behind 1390 Claremont. We observed a cinder block obstructing the flow of water in the V-ditch and this may have caused water to be diverted onto the slope. A relatively large landslide extends from 1360 to 1400 Claremont Drive, with the headscarp located approximately 30 feet downslope from the rear of the houses.

Preliminary Risk Assessment

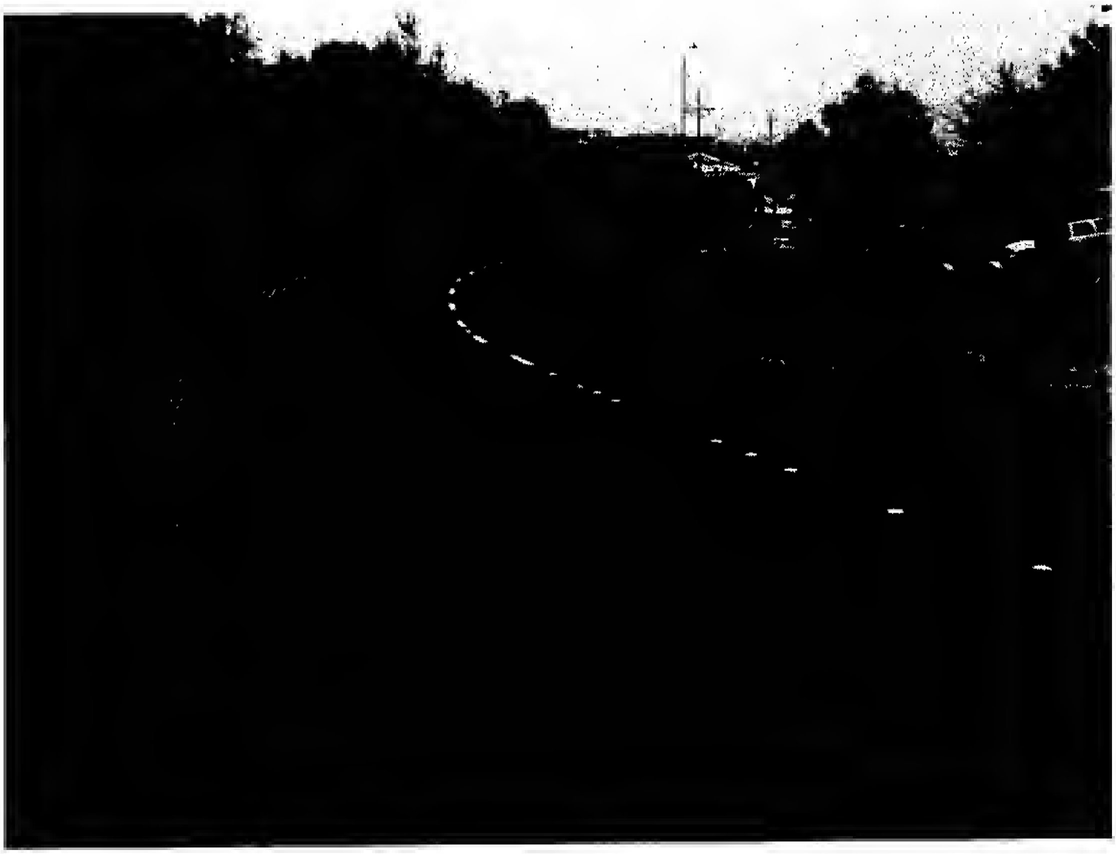
The lack of maintenance and poor condition of the V-ditch has already contributed to slope failures in the area. A **moderate** to **high** risk for future slope failures exists if the V-ditch behind 1360 to 1400 does not convey concentrated storm drainage away from local slopes.

Conclusions and Recommended Actions

Appropriate repairs should be made to restore the functionality of the V-ditch and its flow capacity. The V-ditch should be evaluated throughout its length to identify specific locations for necessary repairs. Specific drainage design details should be prepared by a Civil Engineer to provide adequate capacity to properly convey anticipated flows away from adjacent steep slopes. Repairs should be completed before the onset of the next rainy season.
(See photos 42-49 on CD showing site conditions)

CRESTMOOR CANYON SITE 6

SAN BRUNO AVENUE FILL SLOPE SETTLEMENT



Observed Field Conditions

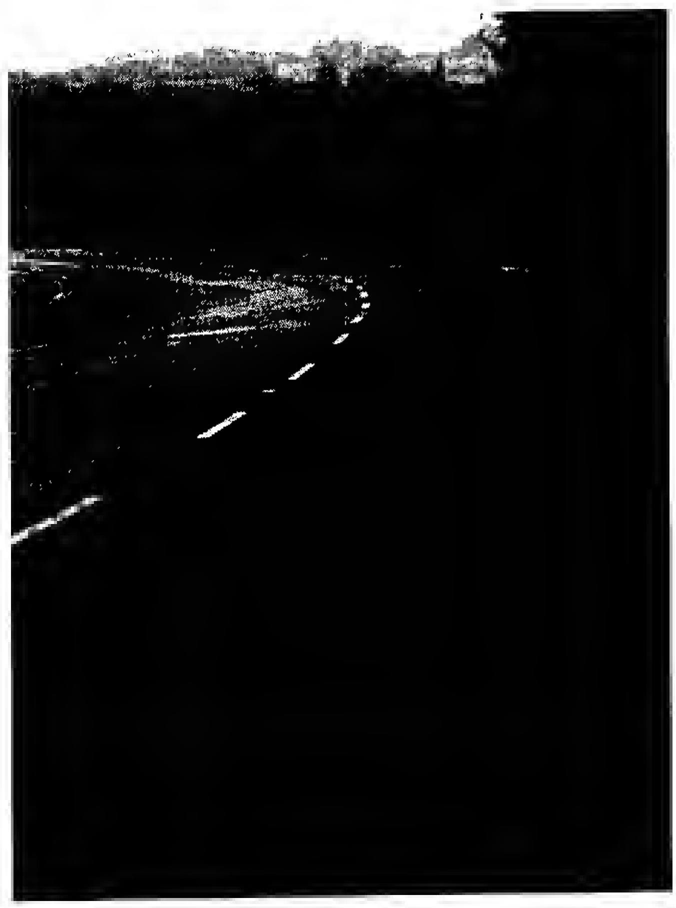
This area is located along a section of San Bruno Avenue situated between Glenview Drive and Crestmoor Drive. The roadway appears to have been been impacted by fill settlement and downslope creep. It appears that fill was placed beneath and on the outboard (downslope) side of San Bruno Avenue between Glenview Drive and Crestmoor Drive associated with the construction of San Bruno Avenue. Two areas of visible sagging, resulting from fill settlement, have formed along San Bruno Avenue. Significant cracking is visible in the westbound lanes of the street as well as buckling of the sidewalk adjacent to the canyon.

Preliminary Risk Assessment

It appears that fill settlement has been on-going since the grading was completed for the construction of San Bruno Avenue. The risk for further settlement and slope creep is **moderate**.

Recommendations

Distress features along San Bruno Avenue and the adjacent fill slopes located to the north should be monitored. If accelerated distress is observed, then the adjacent slope and roadway should be investigated to determine suitable stabilization measures.



CRESTMOOR CANYON SITE 7

BACKYARD V-DITCH MAINTENANCE NEAR TRENTON DRIVE AND CRESTMOOR DRIVE

Observed Field Conditions

This site is located at the northeastern portion of Crestmoor Canyon, along Canyon rim, north of the intersection of Trenton Drive and Crestmoor Drive. The adjacent slopes are predominately north facing, (approximately 45 to 64°) to the north. The area was graded during residential construction that occurred between 1955 and 1958, resulting in the placement of relatively large quantities of fill, with artificial fill slopes established toward the rear of the properties. A concrete-lined V-ditch constructed near the top of the fill slope behind the existing residences appears to start at the property line between 2260 and 2270 Crestmoor Drive and extends east. The ditch is located within the private back yards near the edge of the Canyon. The V-ditch has deteriorated and there are very few stretches that are not broken, completely buried or blocked by obstructions. The ditch is essentially non-functional. However, many residents rely

on this ditch as a means to discharge their yard drainage and roof downspouts. During our site inspection, we noted that most properties have at least one pipe directing drainage to the V-ditch. One residence has a pipe running from their spa to the V-ditch, apparently used to drain the spa into the ditch. A small erosional feature was mapped behind this residence. Evidence of shallow slope instability was also noted on several areas on the slopes behind this portion of Crestmoor Drive.

Preliminary Risk Assessment

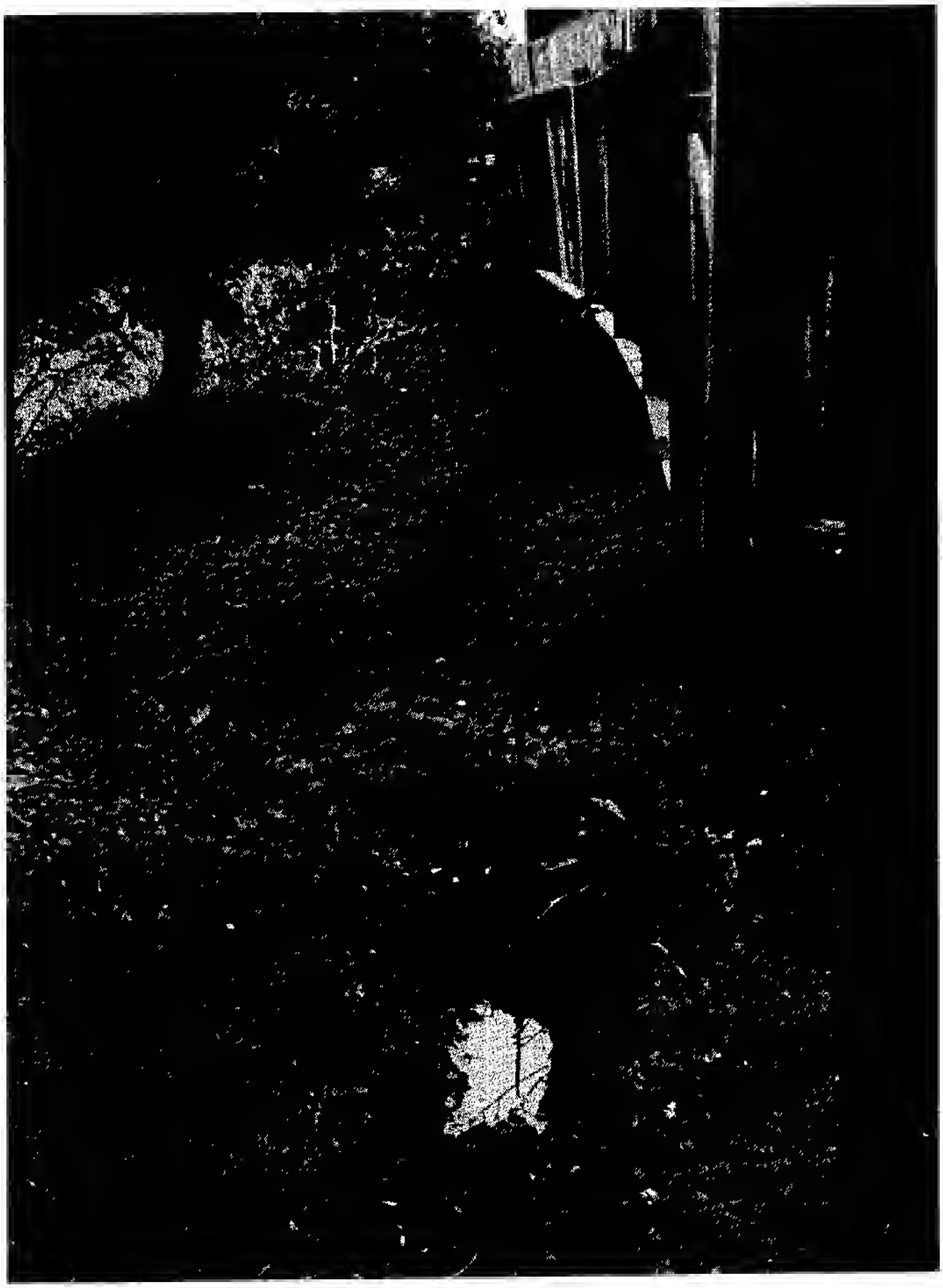
This portion of the canyon rim is characterized by precipitous fill and native slopes. Erosional features or old slope failures have been mapped flanking slopes along this stretch of Crestmoor Drive. A large number of residents rely on the V-ditch to discharge their yard drainage and there are few stretches of intact ditch that properly convey water away from the slopes. The risk of potential future slope instability as a direct result of poorly controlled drainage is **moderate**. The risk of catastrophic damage to existing buildings from drainage related slope failures is judged to be **low**.

Recommendations

Appropriate maintenance should be considered to restore functionality of the original storm drain system. We recommend that concentrated water currently discharged onto local slopes be conveyed away from residential properties in a properly controlled manner. Alternative drainage control structures could be explored if a through-going V-ditch system is not viable.
(See photos 88-91, 94, 96, 99 per Photo Index Map, Plate 2)

CRESTMOOR CANYON SITE 8

UNCONTROLLED DRAINAGE AND EROSION EAST OF 1210-1260 CLAREMONT DRIVE



Observed Field Conditions

This area is located at the eastern side of residences located near the intersection of Claremont Drive and Plymouth Way. At this location we noted several adverse drainage conditions, ongoing erosion and shallow slope instability. Local canyon slopes are characterized by very steep topography (up to approximately 34 degree inclination) northeast-facing hillsides. Extensive grading related to residential construction occurred between 1955 and 1958, resulting in the construction of a large fill prism extending beneath local residences, and a very steep fill slope to the east of the residences.

A V-ditch running adjacent to the fence between 1210 and 1220 Claremont Drive discharges directly onto the slope in back of 1210. This V-ditch may intercept storm drainage overflow from Claremont Drive. A gully has formed near the point of V-ditch discharge. Concrete rip-rap has been placed in this vicinity but has not effectively arrested erosion of the slope.

Surface drainage collected from properties at 1220 and 1230 Claremont are directed into a 24-inch CMP culvert that runs beneath the yard at 1220 and continues downslope, eventually discharging onto steep slopes and into a 15-foot deep gulley. Immediately behind 1220 and 1230 Claremont, concrete rip-rap has been placed on the slope and is overgrown with vegetation. Cracking of the ground was observed at the rear of 1220 Claremont suggesting early stages of slope instability.

Additional signs of inadequate surface drainage control and slope instability were observed immediately east of 1240, 1250 and 1260 Claremont. The concrete V-ditch was absent behind 1240; the ditch was broken and inadequately maintained behind 1250; and the ditch was entirely buried behind 1260 Claremont. Canyon slopes east of the ditch show signs of erosion and shallow slope instability.

Preliminary Risk Assessment

The steep slopes east of 1210 to 1260 Claremont Drive have been damaged by erosion and shallow landsliding. The potential for future instability of this slope is high without improved control of surface drainage. The potential for slope instability to impact private property at 1220 and 1240 is moderate to high.

Recommendations

A functional system should be re-established for collecting and conveying surface drainage away from properties at 1210 through 1260 Claremont Drive. A concrete V-ditch system along the rear yards of these properties will only be effective if properly maintained. All points of drainage discharge into the canyon beyond these residences should be examined to determine where upgrades are warranted. We

recommend that the 24-inch CMP extending east of 1220 Claremont be inspected in greater detail for corrosion. We anticipate that this pipe may warrant replacement or slip-lining. Areas of active erosion should receive appropriate erosion control measures. (See photos 57-63)

CRESTMOOR CANYON SITE 9

SURFACE DRAINAGE CONTROL ACROSS EXISTING REPAIRED SLOPE EAST AND SOUTHEAST OF CONCORD WAY

Observed Field Conditions

This area is located at the western side of Crestmoor Canyon, below the terminus of Concord Way and extending along the slope in back of Claremont Drive from Concord Way to 1510 Claremont Drive. Existing east-facing fill slopes are generally steep (up to 26 degrees) and extend down to the canyon access road. The hillside has undergone at least two generations of extensive grading related to residential construction that occurred between 1955 and 1958, resulting in the placement of large quantities of fill, as well as a 1983 landslide repair.

This area experienced storm related landslide failure in 1983. Storm drainage was formerly directed from the upslope housing developments to the edge of the canyon, where it ultimately discharged onto the slope. A major landslide repair was completed

by removing landslide debris and keying and benching engineered fill into the hillside. Concrete lined V-ditches were constructed on the final terraced slope. Sediment has filled in the ditches and the area is overgrown with brush. At the time of our site visit, the concrete V-ditches were generally obscured by soil and vegetation. No significant signs of erosion were observed on the well vegetated slope.

Preliminary Risk Assessment

Both V-ditches are essentially non-functional. The intent of installing V-ditches on the fill slope was apparently to intercept drainage and divert it away from the slope. The current state of the V-ditches is not consistent with the initial design intent. The level of risk associated with the unmaintained ditch is undetermined; however, no significant erosion was observed at the repaired slope during our site inspections.

Recommendations

We recommend that the V-ditches be cleaned and checked to confirm that they are able to adequately convey the surface water away from the repaired area, as designed.
(See photo 41 on CD for site conditions)

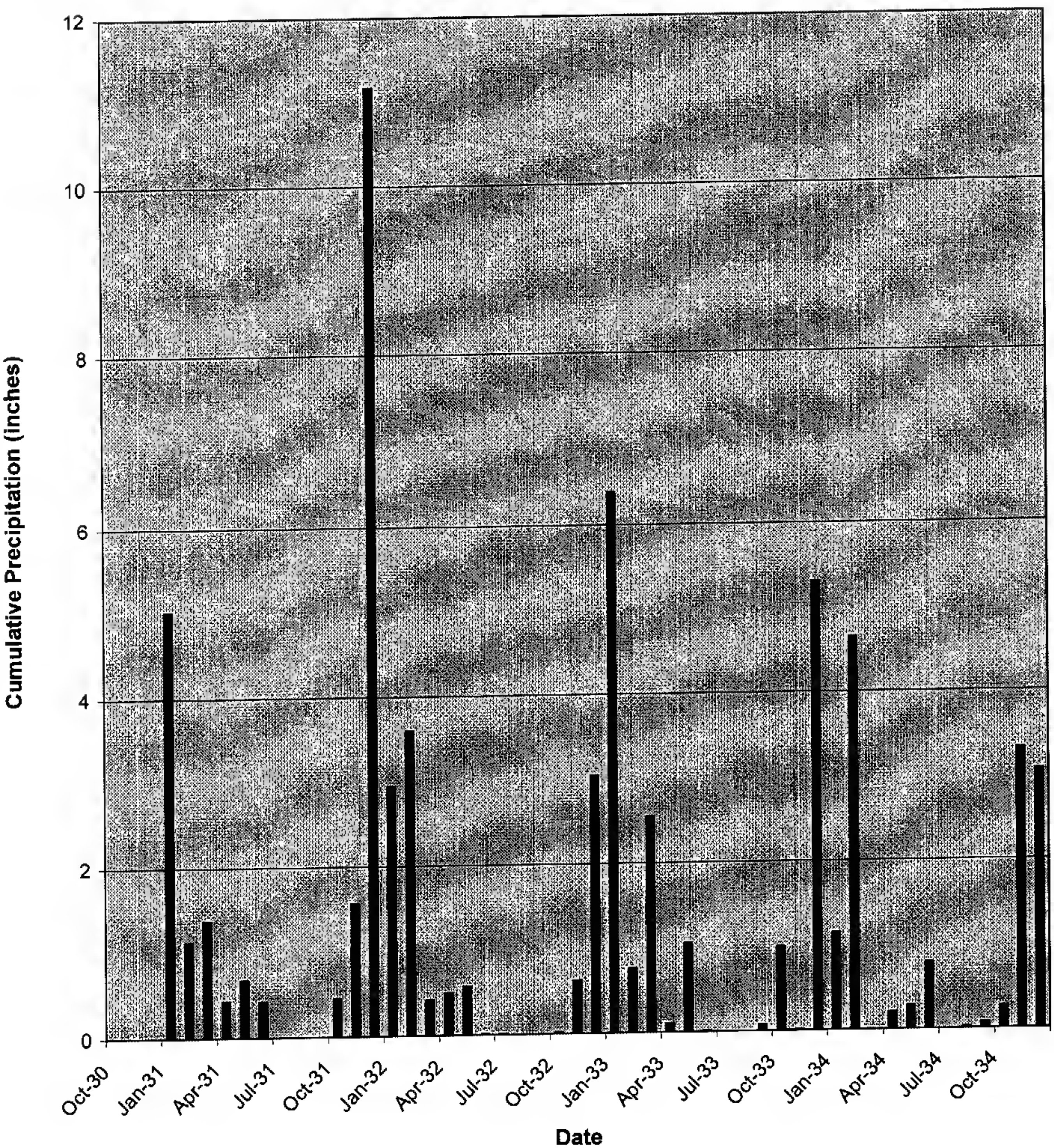
APPENDIX B

Supplemental Data

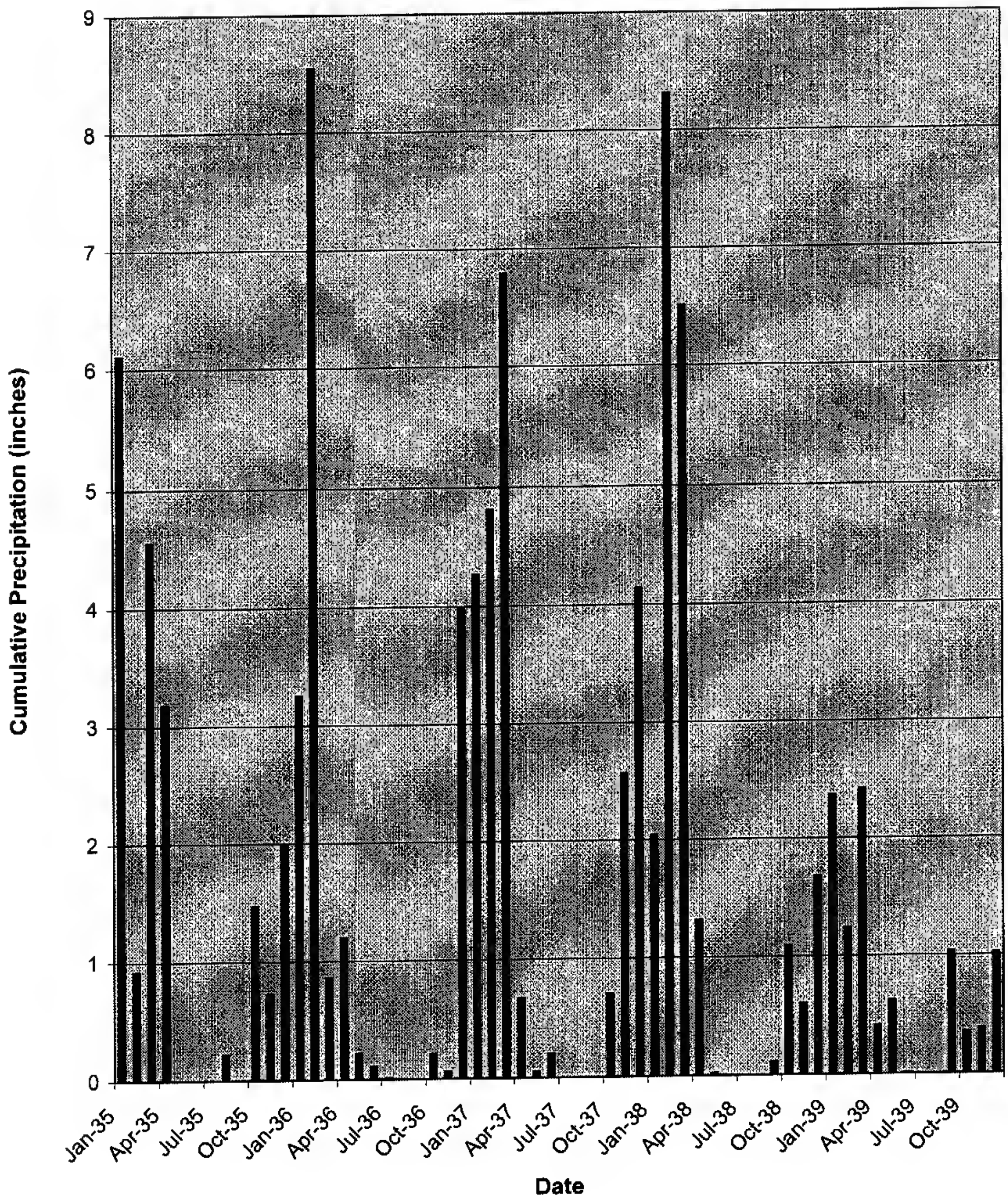
RAINFALL DATA

Rainfall data for the San Bruno area was downloaded from the Department of Water Resources (C)alifornia (D)ata (E)xchange (C)enter (cdec.water.ca.gov). The most local station to Crestmoor Canyon is located at San Francisco International Airport (station SFF on the CDEC website). The data is presented in bar graphs representing monthly accumulated precipitation, collected from 1930 to 2007.

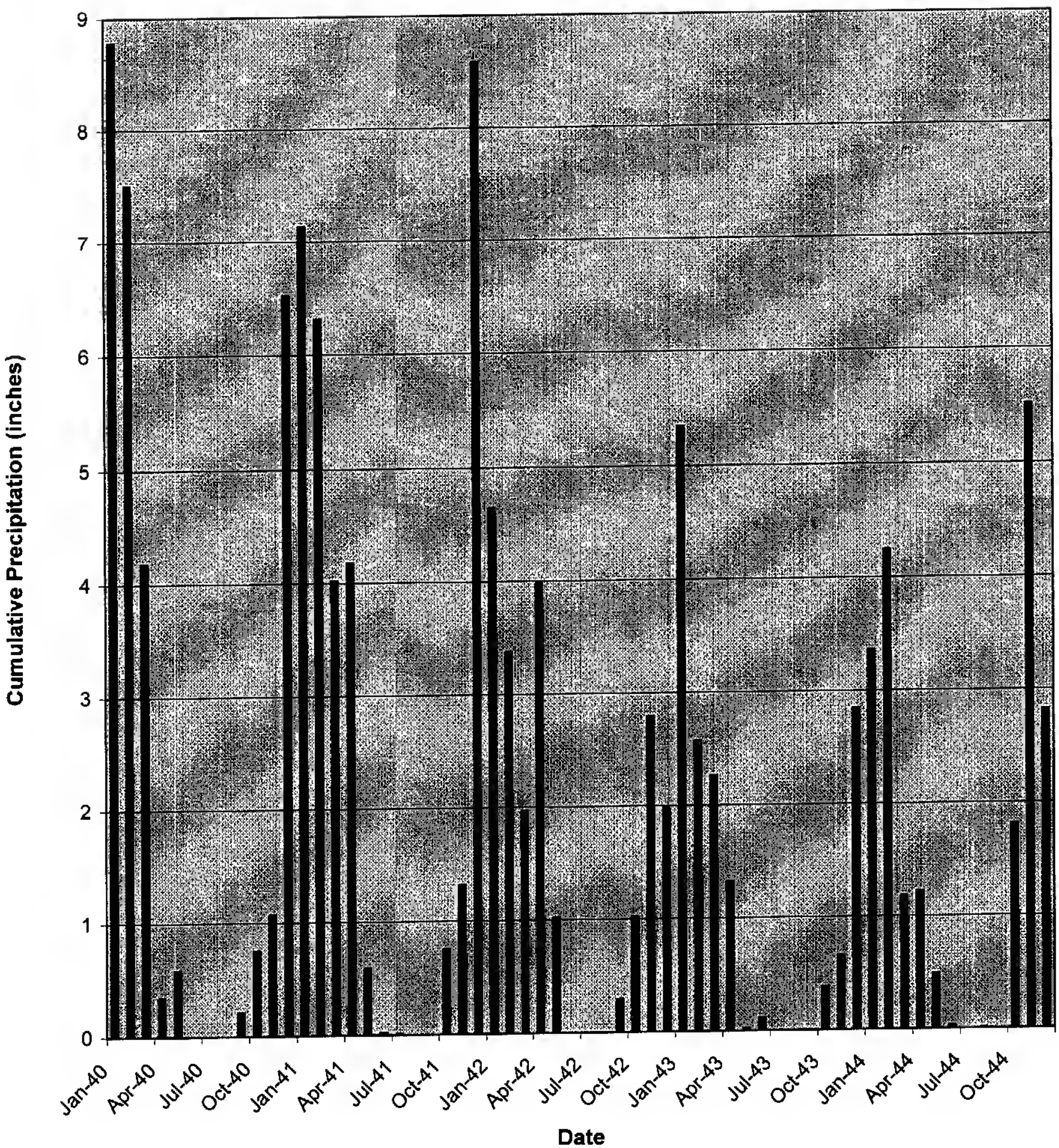
Rainfall Data for 1930-1934



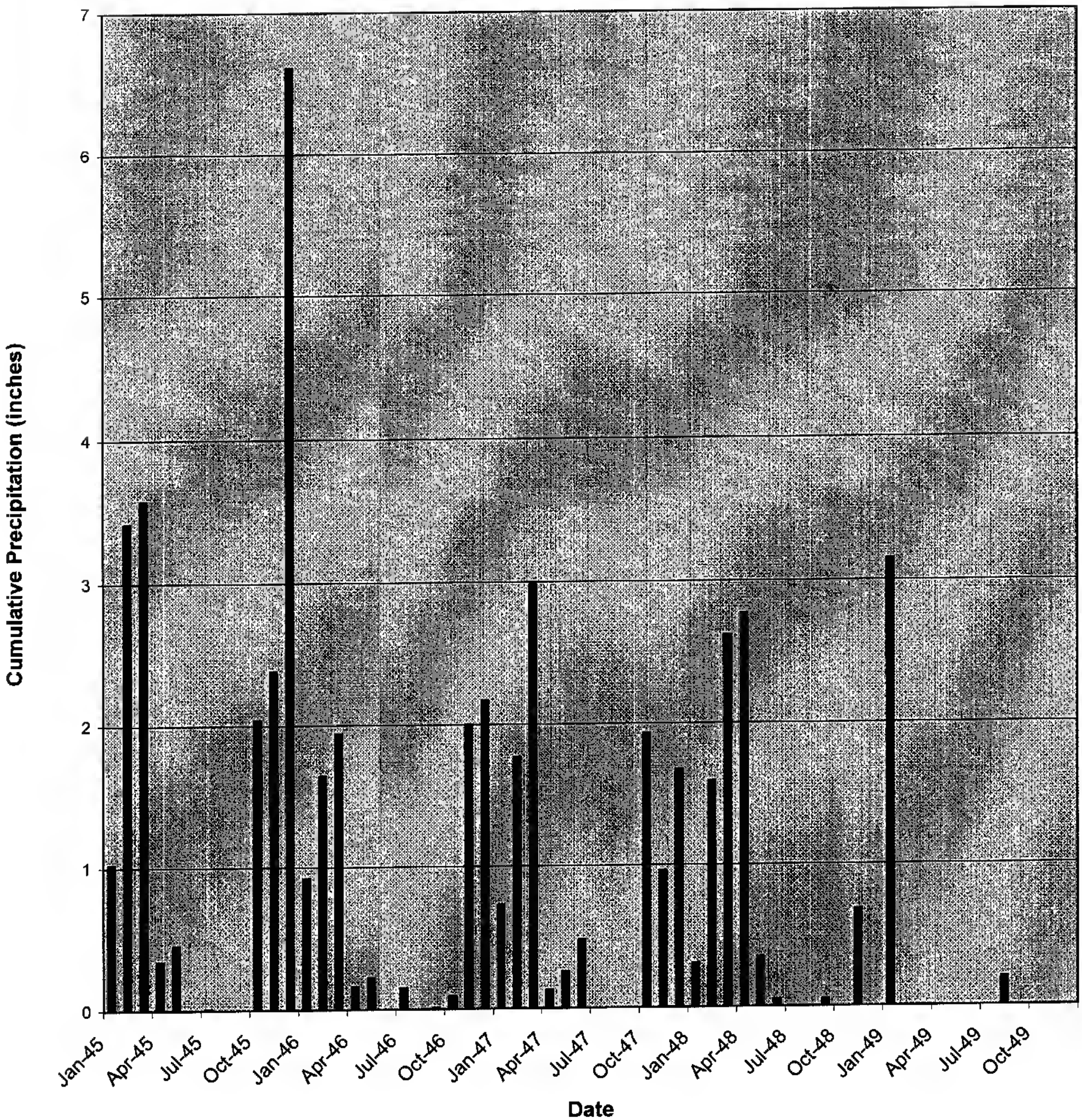
Rainfall for 1935-1939



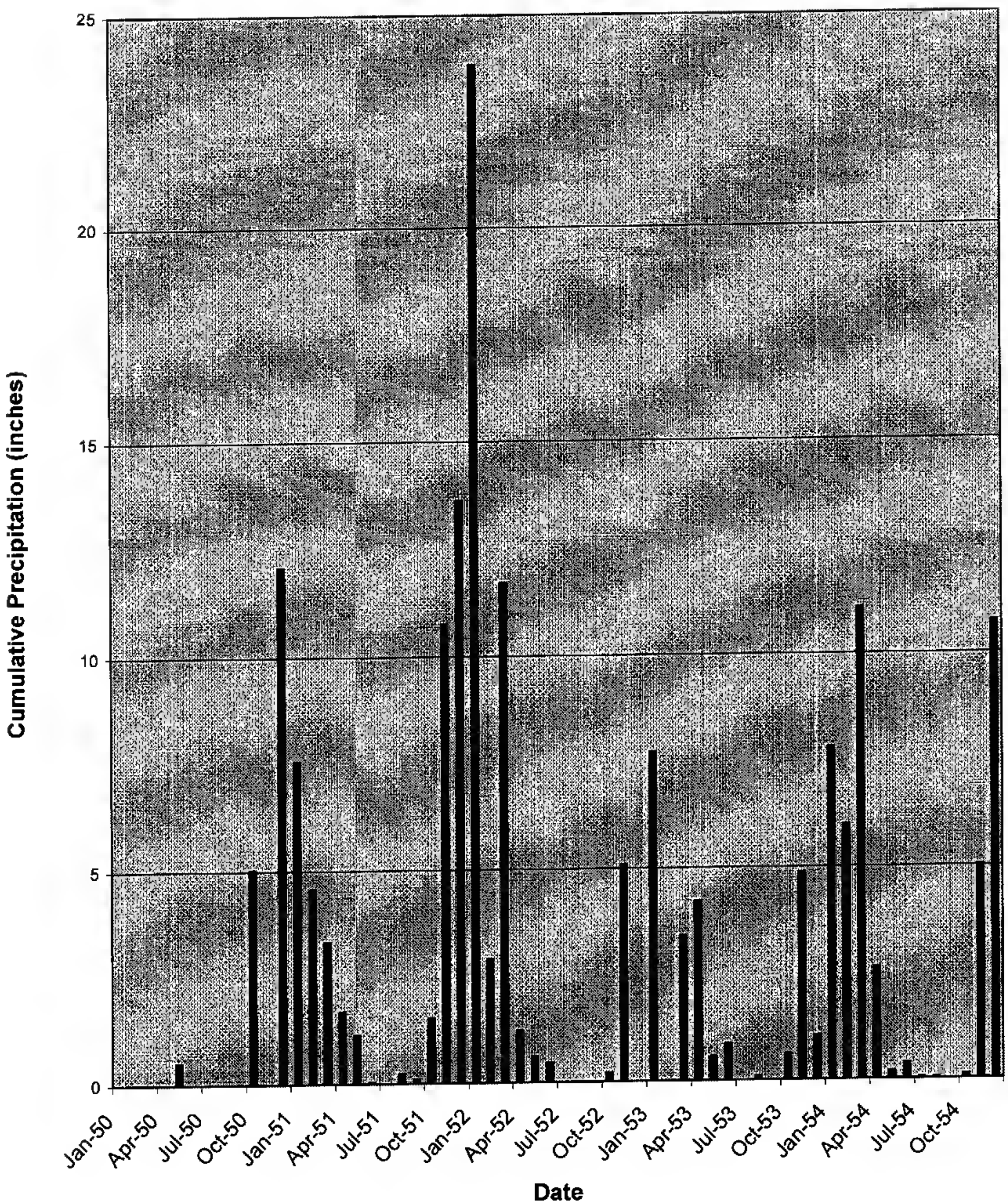
Rainfall for 1940-1944



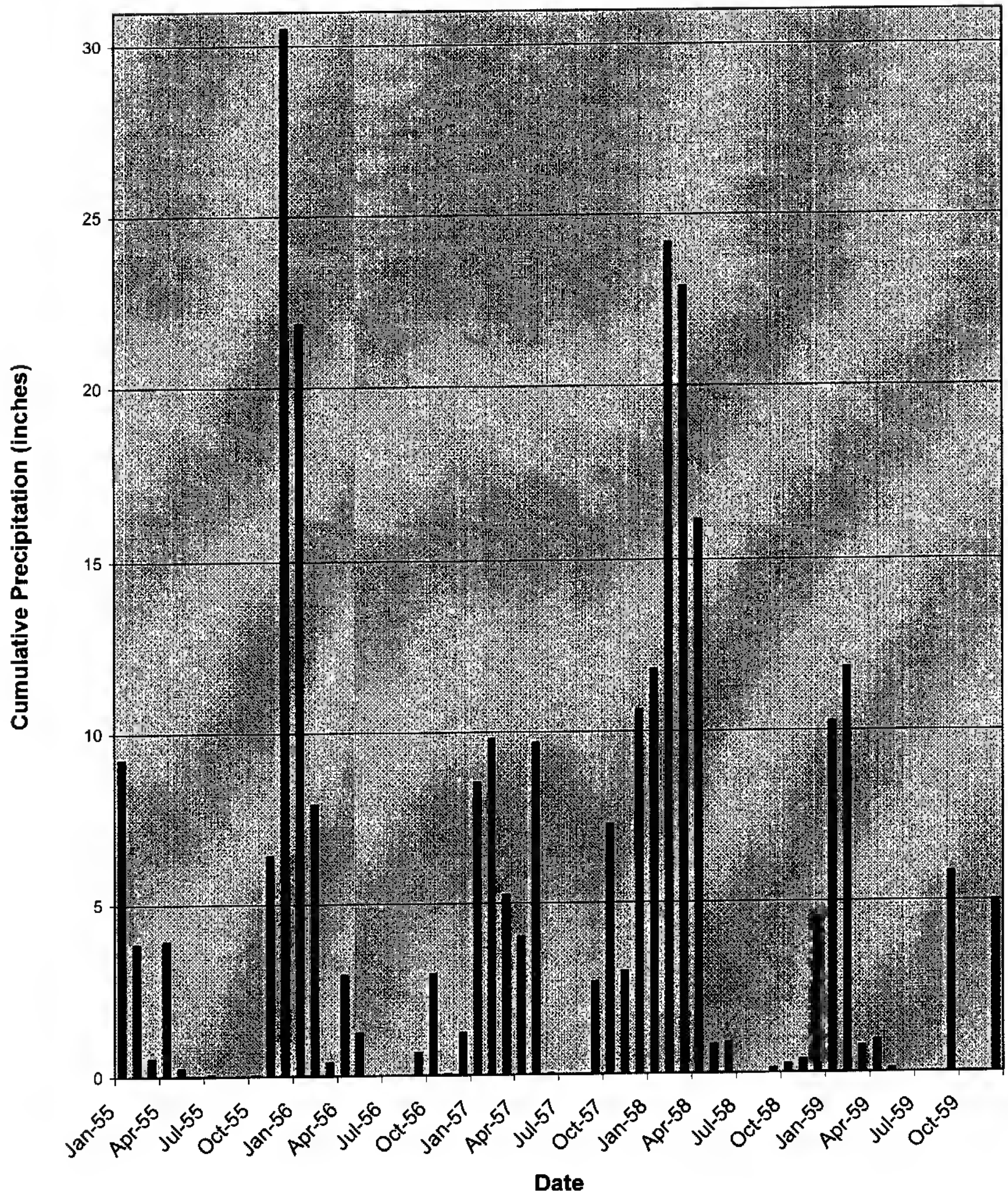
Rainfall Data for 1945-1949



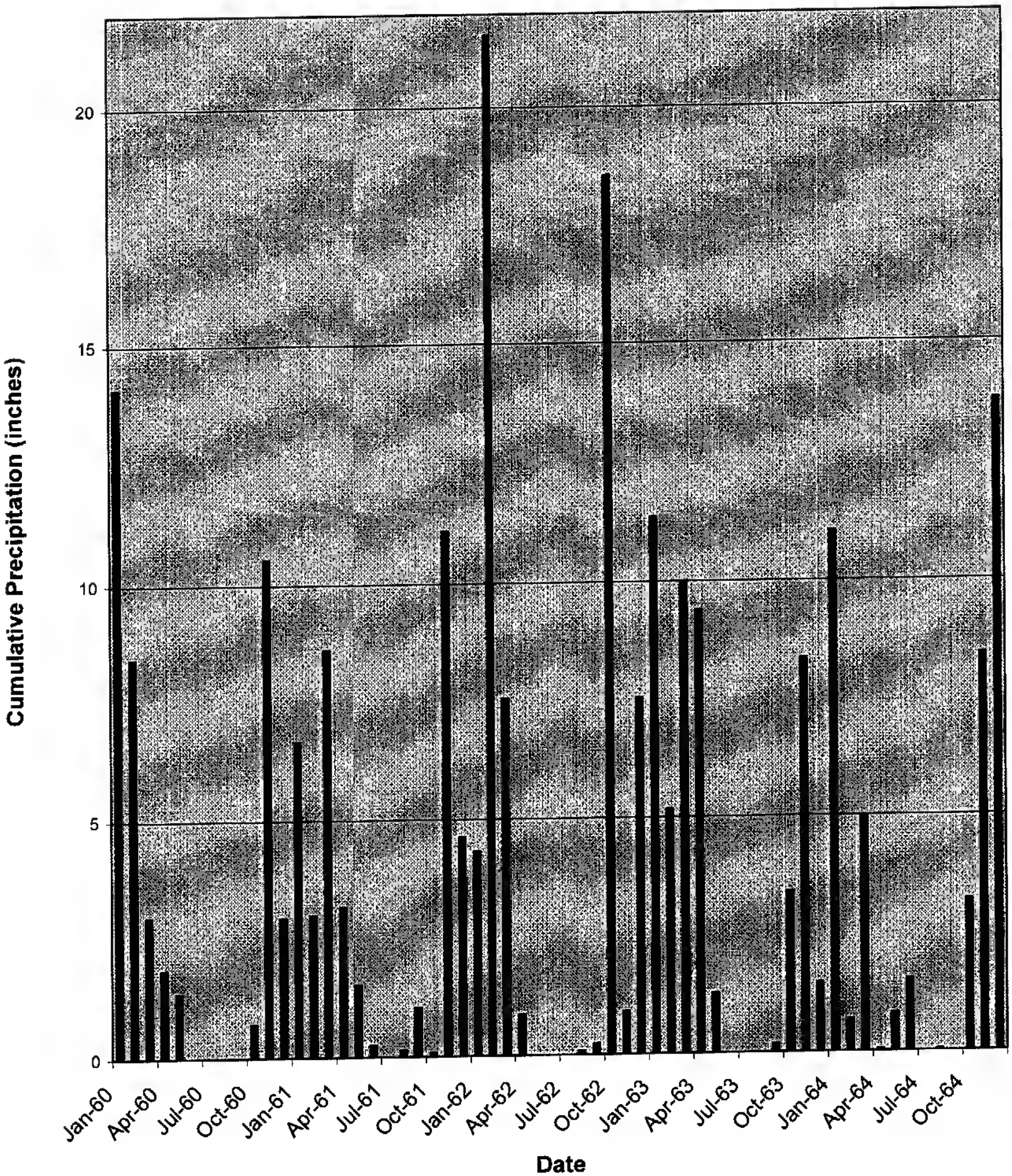
Rainfall for 1950-1954

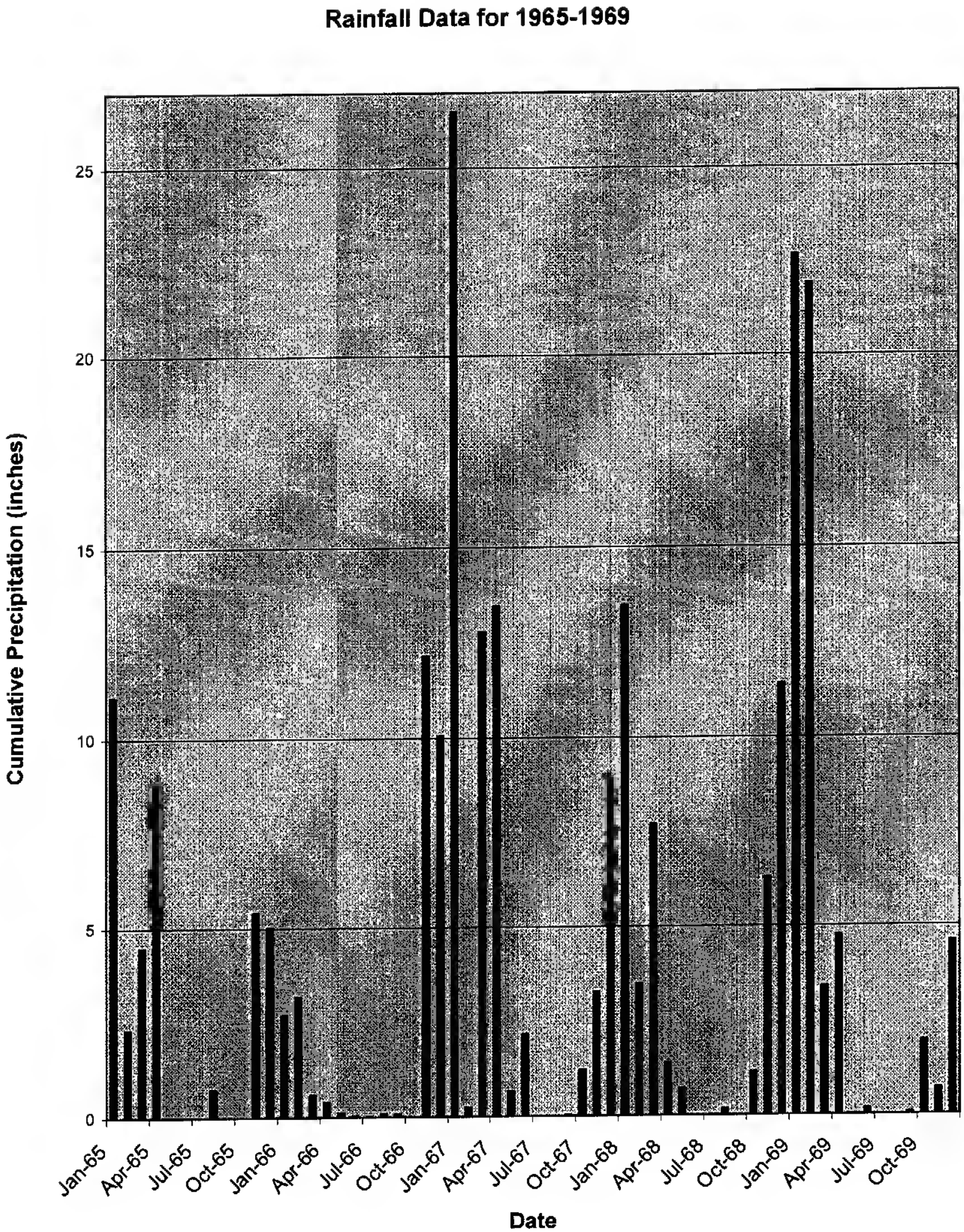


Rainfall Data for 1955-1959

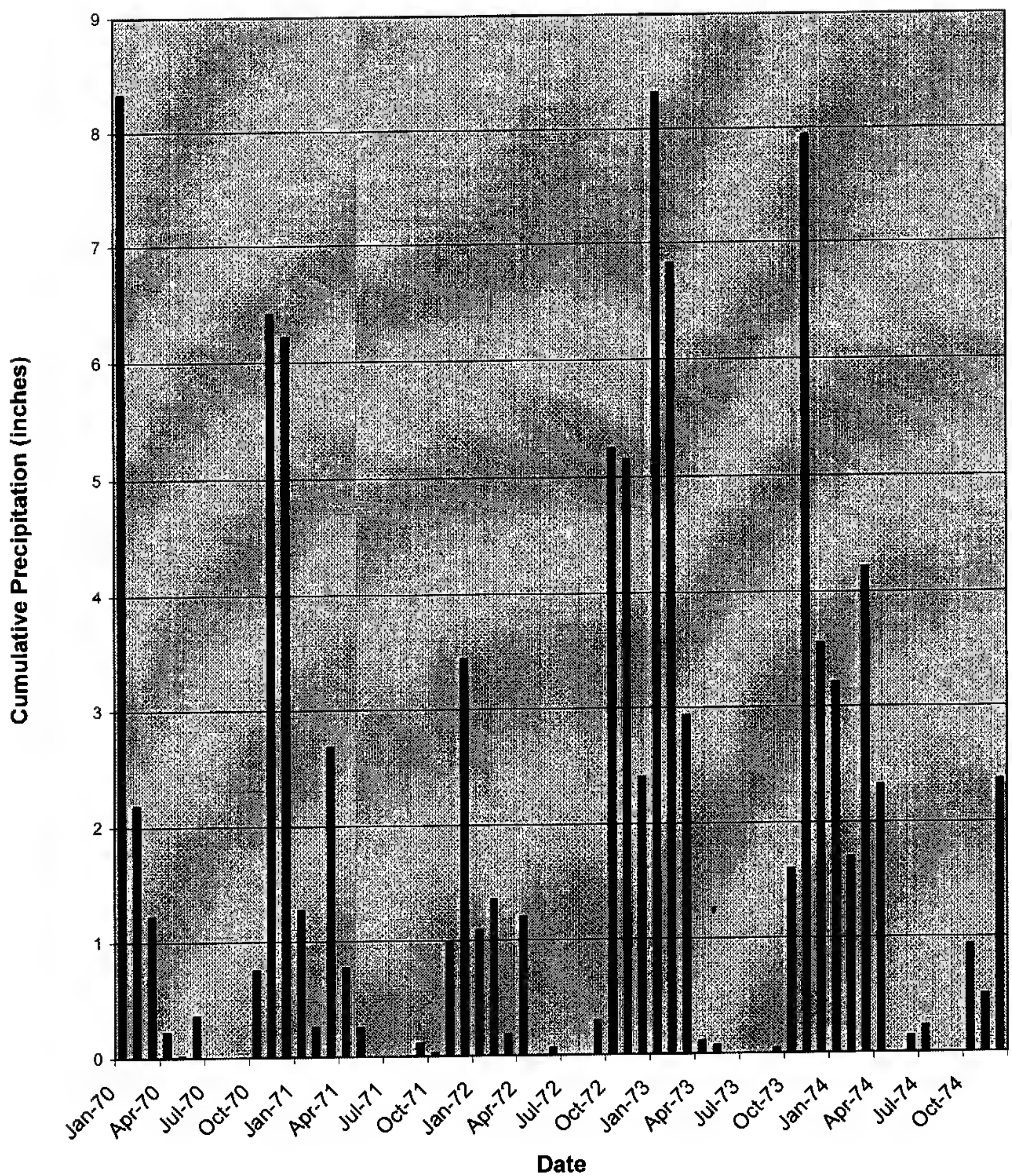


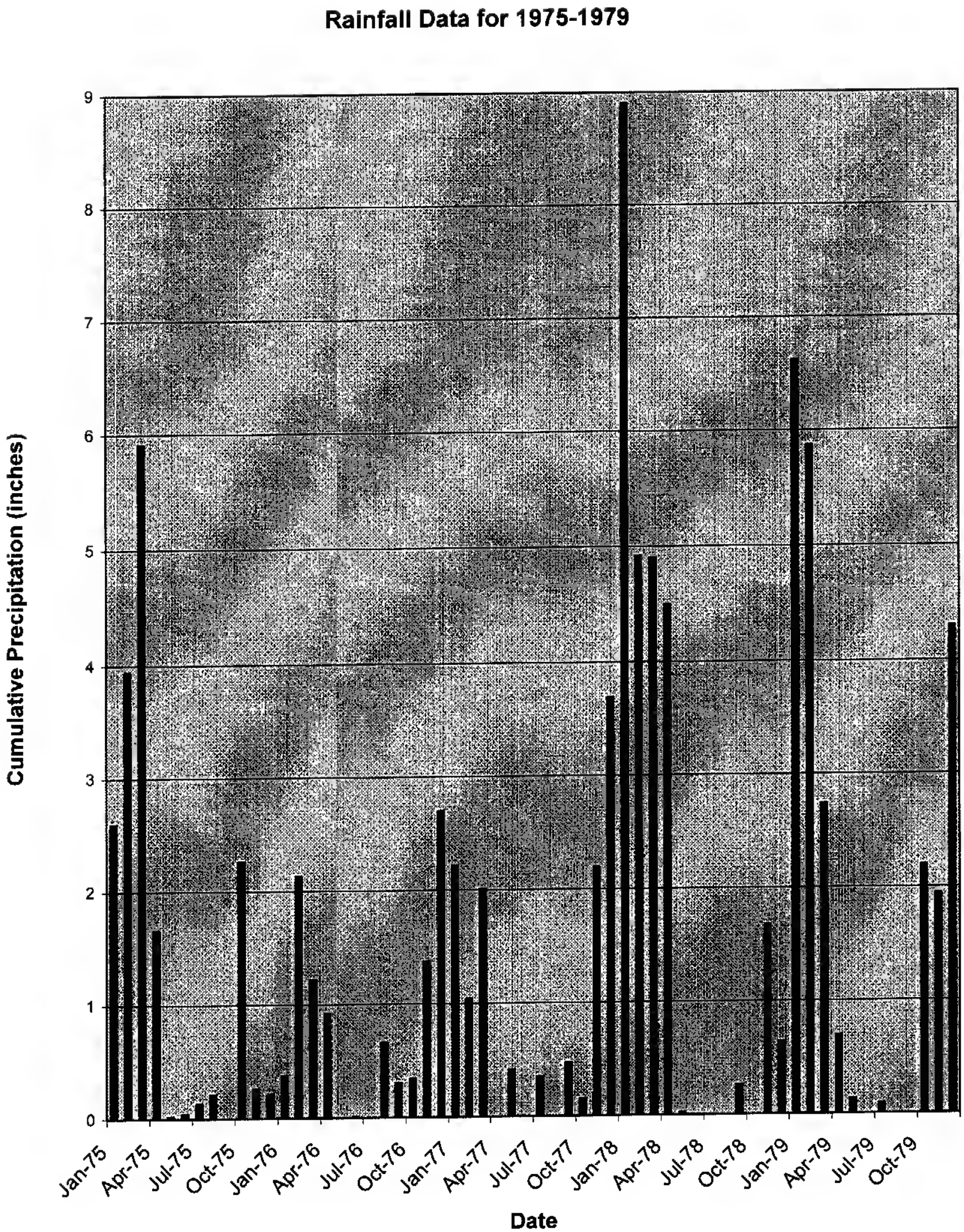
Rainfall for 1960-1964




Rainfall Data for 1965-1969
Cumulative Precipitation (inches)
25
20
15
10
5
0
Jan-65
Apr-65
Jul-65
Oct-65
Jan-66
Apr-66
Jul-66
Oct-66
Jan-67
Apr-67
Jul-67
Oct-67
Jan-68
Apr-68
Jul-68
Oct-68
Jan-69
Apr-69
Jul-69
Oct-69
Date

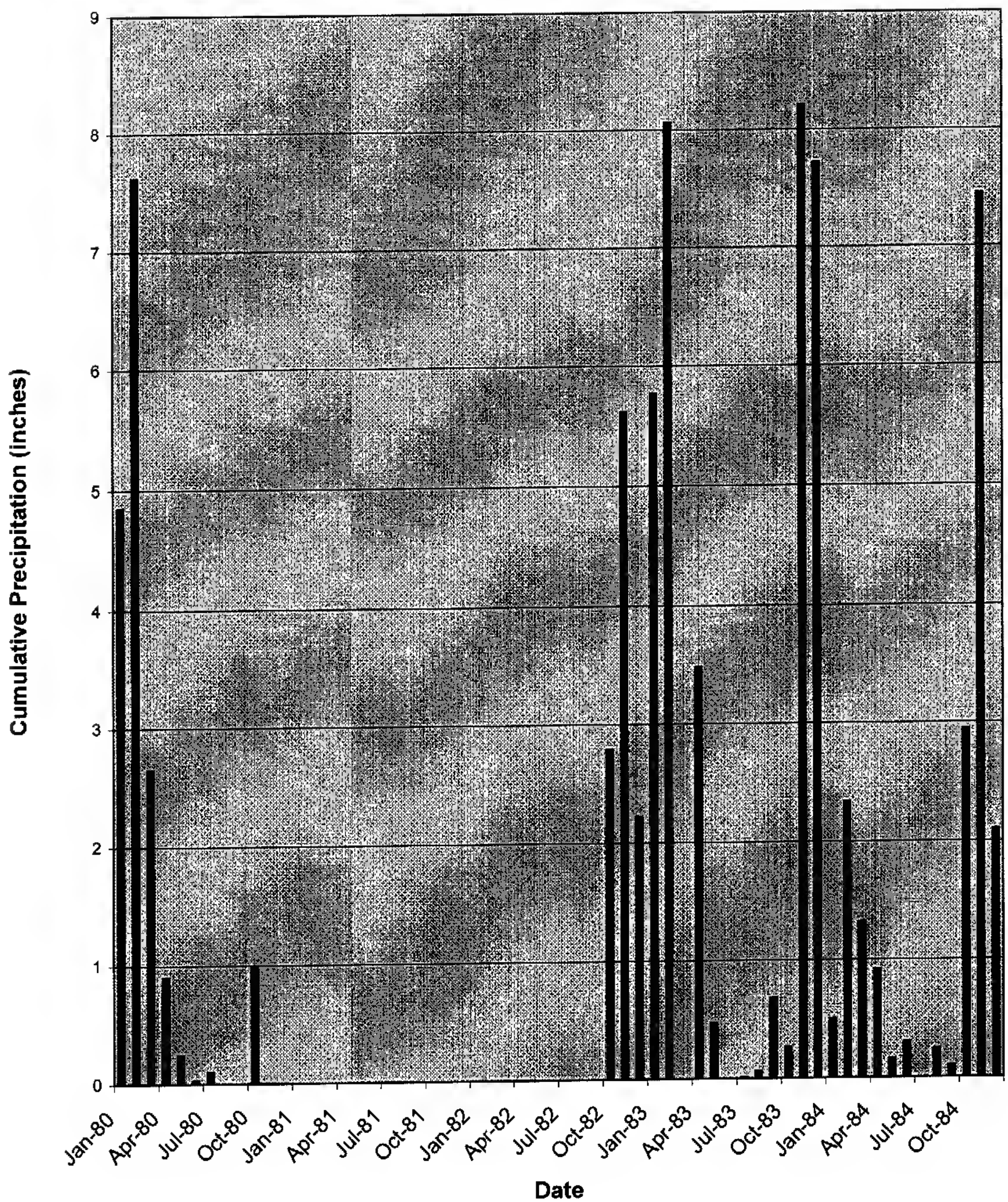
Rainfall for 1970-1974



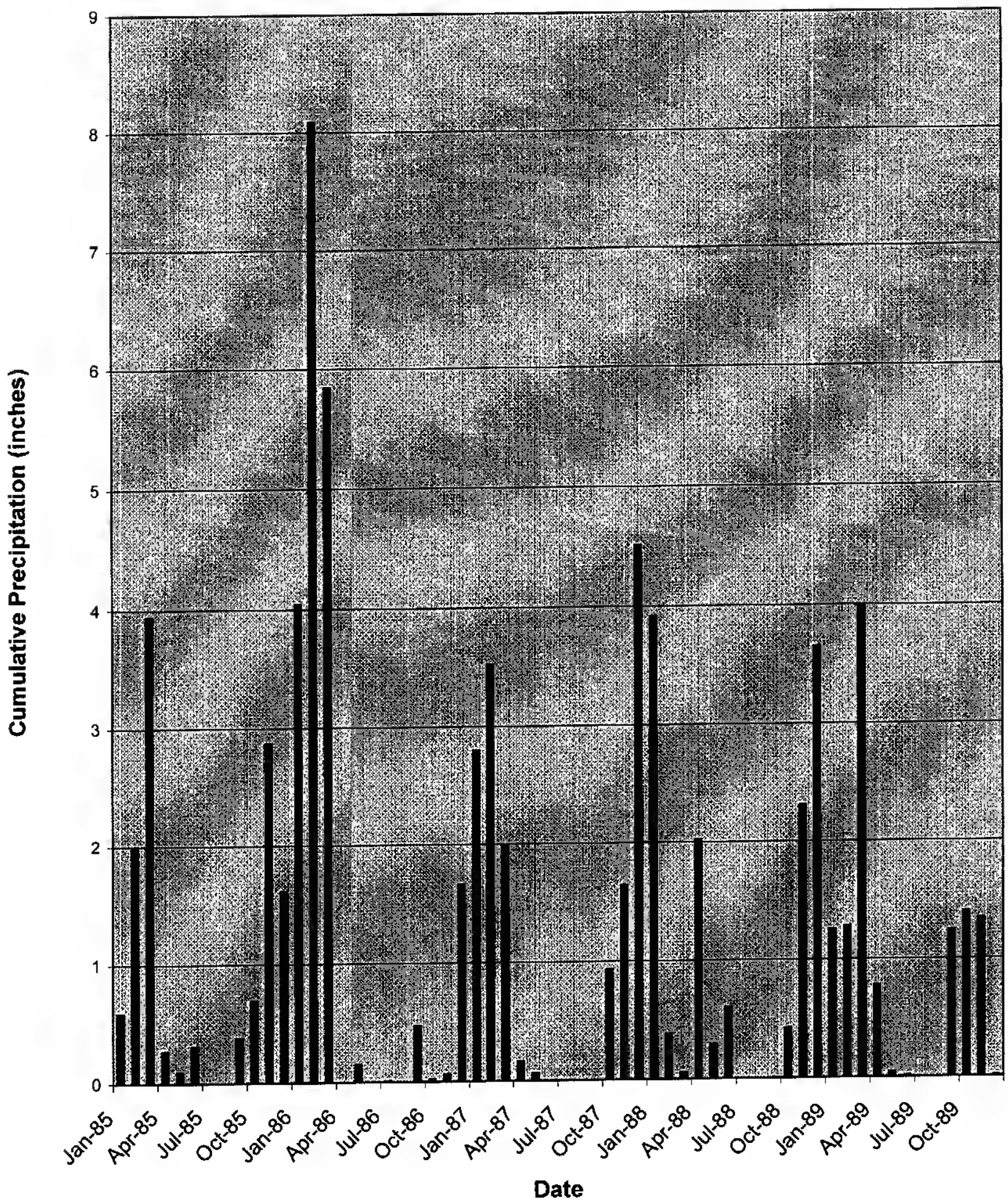


Rainfall Data for 1975-1979
Cumulative Precipitation (inches)
0
1
2
3
4
5
6
7
8
9
Jan-75
Apr-75
Jul-75
Oct-75
Jan-76
Apr-76
Jul-76
Oct-76
Jan-77
Apr-77
Jul-77
Oct-77
Jan-78
Apr-78
Jul-78
Oct-78
Jan-79
Apr-79
Jul-79
Oct-79
Date

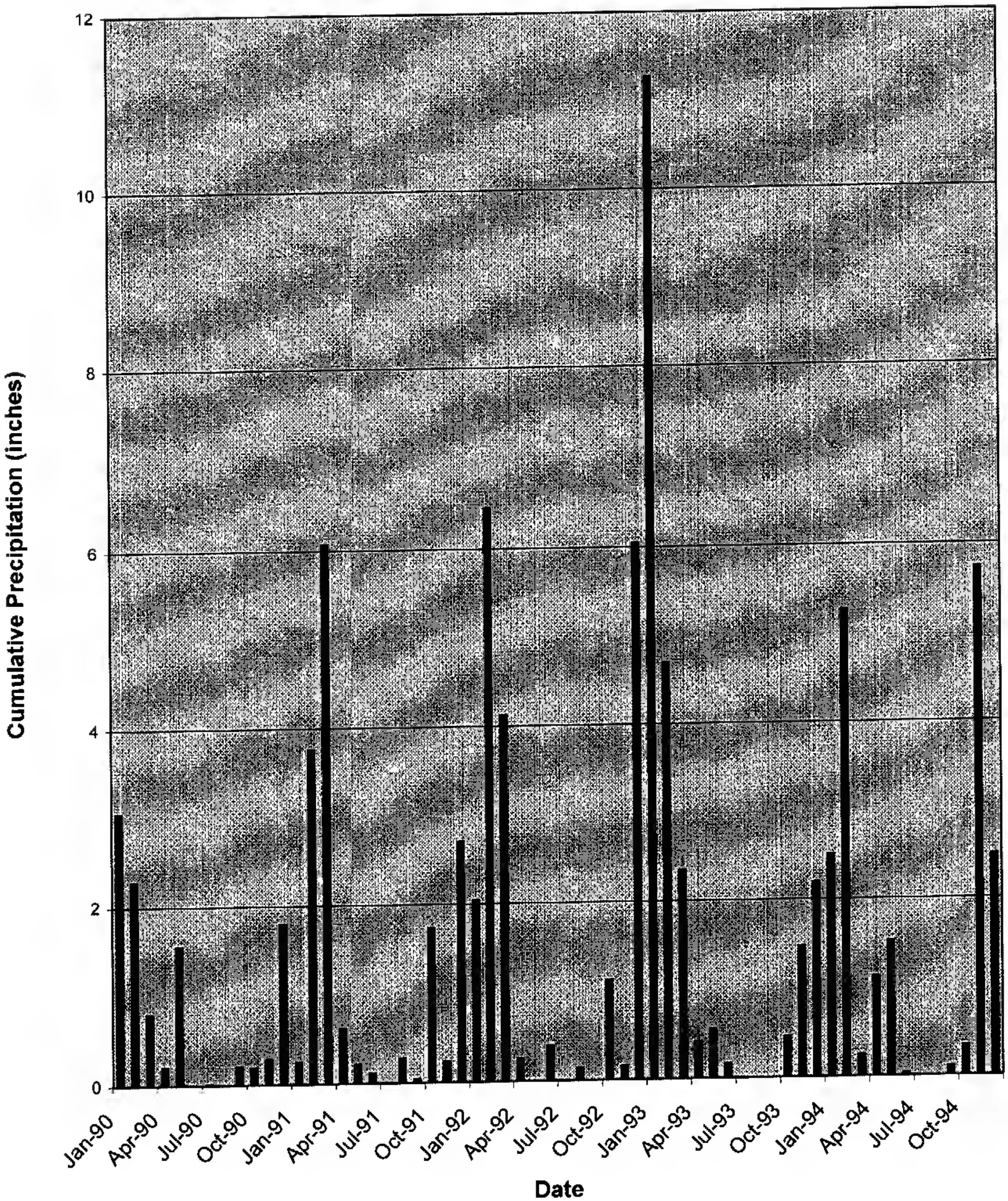
Rainfall Data for 1980-1984

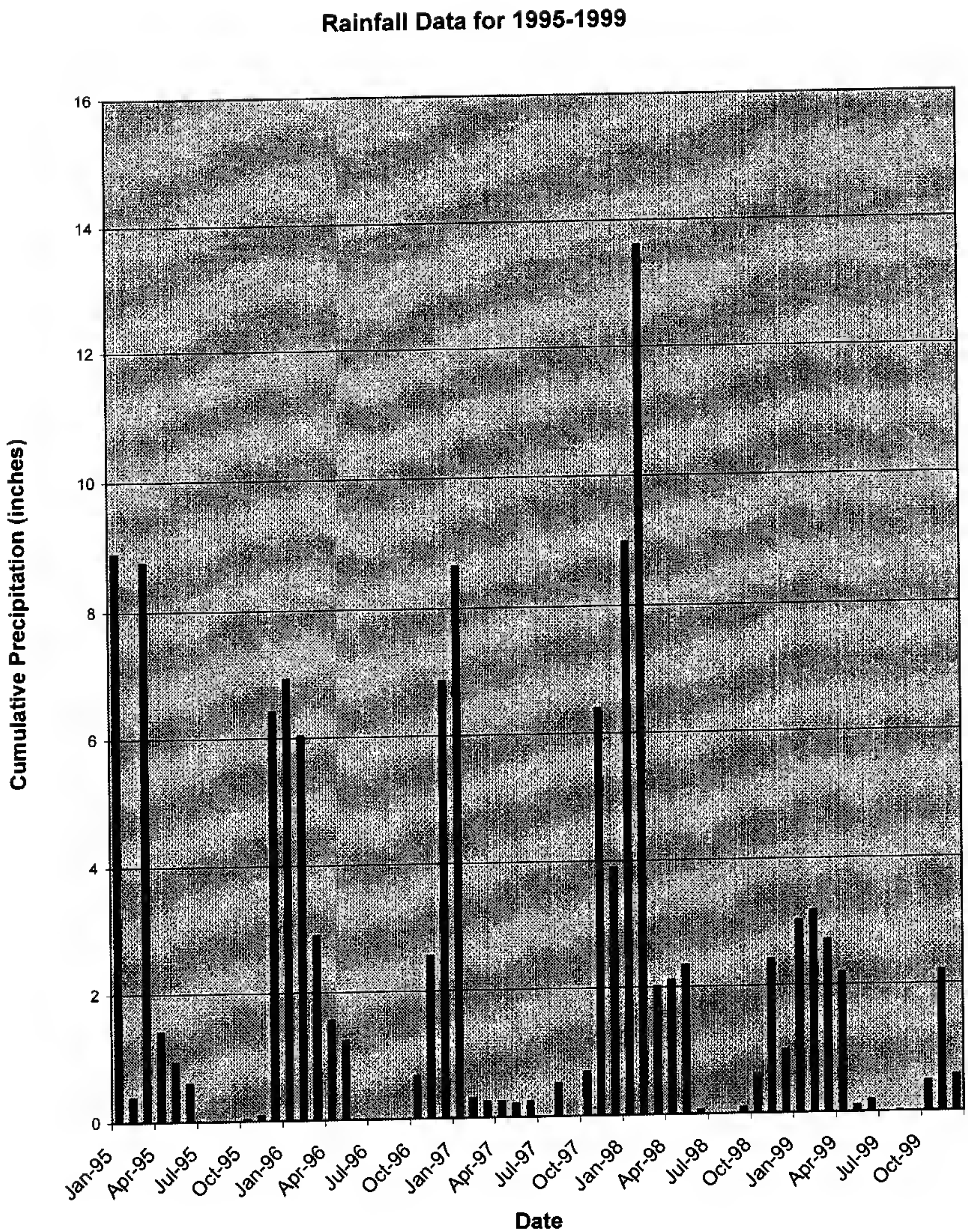


Rainfall Data for 1985-1989

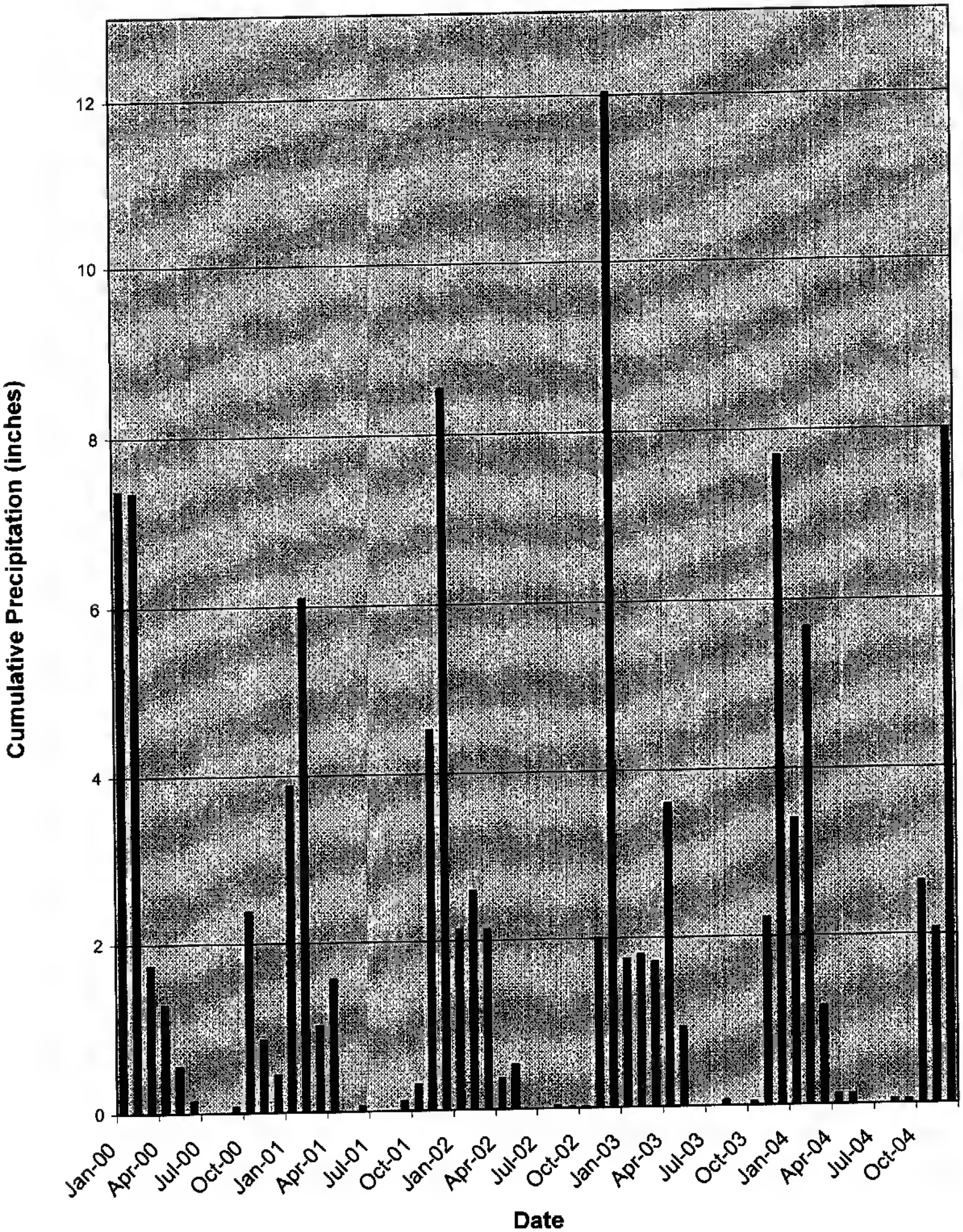


Rainfall for 1990-1994




Rainfall Data for 1995-1999
Cumulative Precipitation (inches)
16
14
12
10
8
6
4
2
0
Jan-95
Apr-95
Jul-95
Oct-95
Jan-96
Apr-96
Jul-96
Oct-96
Jan-97
Apr-97
Jul-97
Oct-97
Jan-98
Apr-98
Jul-98
Oct-98
Jan-99
Apr-99
Jul-99
Oct-99
Date

Rainfall for 2000-2004



Rainfall Data for 2005-2007